



US011453146B2

(12) **United States Patent**  
**Luharuka et al.**

(10) **Patent No.:** **US 11,453,146 B2**  
(45) **Date of Patent:** **Sep. 27, 2022**

(54) **HYDRATION SYSTEMS AND METHODS**

(71) Applicant: **Schlumberger Technology Corporation**, Sugar Land, TX (US)

(72) Inventors: **Rajesh Luharuka**, Katy, TX (US); **Hau Nguyen-Phuc Pham**, Houston, TX (US); **Jonathan Wun Shiung Chong**, Sugar Land, TX (US); **Miguel Angel Lopez**, Sugar Land, TX (US); **Rod William Champine**, Houston, TX (US); **Gocha G. Chochua**, Sugar Land, TX (US); **Mark Maher Hakim Ayyad**, Sugar Land, TX (US)

(73) Assignee: **Schlumberger Technology Corporation**, Sugar Land, TX (US)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 394 days.

(21) Appl. No.: **14/709,778**

(22) Filed: **May 12, 2015**

(65) **Prior Publication Data**  
US 2015/0240148 A1 Aug. 27, 2015

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 14/536,415, filed on Nov. 7, 2014, now Pat. No. 9,457,335, and a (Continued)

(51) **Int. Cl.**  
**B29B 7/60** (2006.01)  
**E21B 43/26** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **B29B 7/60** (2013.01); **B29B 7/40** (2013.01); **B29B 7/72** (2013.01); **B29B 7/748** (2013.01);

(Continued)

(58) **Field of Classification Search**  
CPC .... **B29B 7/60**; **B29B 7/40**; **B29B 7/72**; **B29B 7/748**; **B29B 7/7485**; **B29B 7/603**; **C09K 8/66**; **E21B 43/26**

(Continued)

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

559,965 A 5/1896 Bierstadt  
896,233 A 8/1908 McQueen  
(Continued)

**FOREIGN PATENT DOCUMENTS**

CA 2643743 C 4/2011  
CN 2601189 Y 1/2004  
(Continued)

**OTHER PUBLICATIONS**

International Search Report and Written Opinion issued in International Application No. PCT/US2015/017175, dated May 28, 2015, 16 pages.

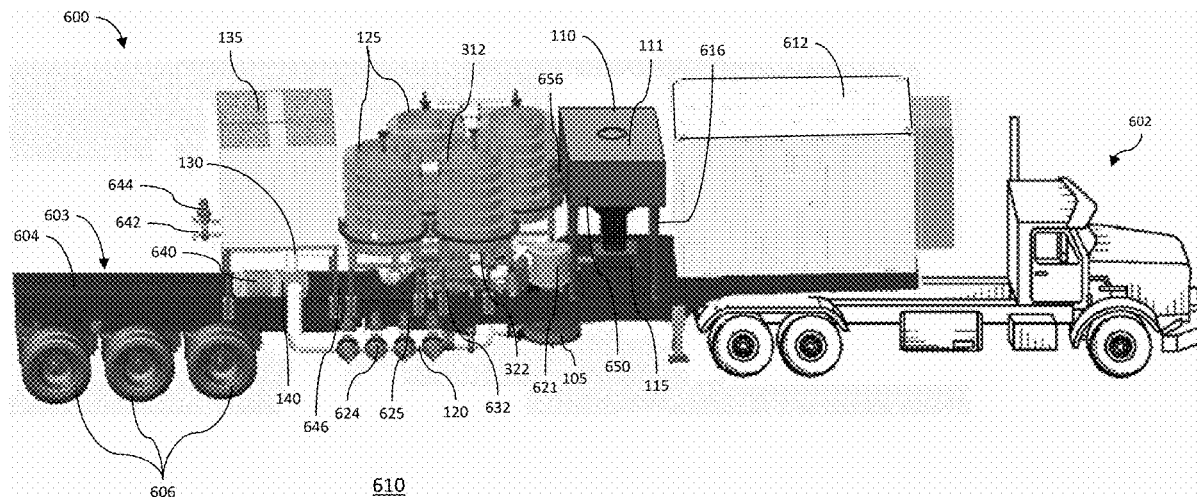
(Continued)

*Primary Examiner* — Marc C Howell

(57) **ABSTRACT**

A substantially continuous stream of aqueous fluid and a substantially continuous stream of gel having a first concentration are combined to form a substantially continuous stream of gel having a second concentration. The second concentration is substantially lower than the first concentration. The gel having the second concentration may thereafter be utilized in conjunction with a well fracturing operation.

**18 Claims, 10 Drawing Sheets**



<b>Related U.S. Application Data</b>					
	continuation-in-part of application No. 14/192,838, filed on Feb. 27, 2014.		4,268,208 A	5/1981	Hankins et al.
			4,337,014 A	6/1982	Farnham
			4,348,146 A	9/1982	Brock
			4,373,857 A	2/1983	Giles
			4,375,343 A	3/1983	Butler
			4,400,126 A	8/1983	Desourdy
(60)	Provisional application No. 61/991,685, filed on May 12, 2014.		4,427,133 A	1/1984	Kierbow et al.
			4,453,829 A	6/1984	Althouse
			4,465,420 A	8/1984	Dillman
(51)	<b>Int. Cl.</b>		4,494,903 A	1/1985	Badicel et al.
	<b>B29B 7/40</b> (2006.01)		4,561,821 A	12/1985	Dillman
	<b>B29B 7/72</b> (2006.01)		4,579,496 A	4/1986	Gerlach
	<b>B29B 7/88</b> (2006.01)		4,601,628 A	7/1986	Lowling
	<b>B29B 7/74</b> (2006.01)		4,621,972 A	11/1986	Grotte
	<b>C09K 8/66</b> (2006.01)		4,624,357 A	11/1986	Oury et al.
			4,626,166 A	12/1986	Jolly
(52)	<b>U.S. Cl.</b>		4,671,665 A	6/1987	McIntire
	CPC ..... <b>B29B 7/7485</b> (2013.01); <b>B29B 7/88</b> (2013.01); <b>C09K 8/66</b> (2013.01); <b>E21B 43/26</b> (2013.01); <b>B29B 7/402</b> (2013.01); <b>B29B 7/603</b> (2013.01)		4,701,095 A	10/1987	Berryman et al.
			4,775,275 A	10/1988	Perry
			4,808,004 A	2/1989	Mcintire et al.
			4,832,561 A	5/1989	Nijenhuis
			4,834,542 A	5/1989	Sherwood
(58)	<b>Field of Classification Search</b>		4,850,750 A	7/1989	Cogbill et al.
	USPC ..... 366/138		4,855,960 A	8/1989	Janssen et al.
	See application file for complete search history.		4,883,363 A	11/1989	Pillon et al.
			4,899,832 A	2/1990	Bierscheid, Jr.
			4,907,712 A	3/1990	Stempin
(56)	<b>References Cited</b>		4,917,560 A	4/1990	Murray et al.
	<b>U.S. PATENT DOCUMENTS</b>		4,925,358 A	5/1990	Cook
			4,944,646 A	7/1990	Edwards et al.
			5,006,034 A	4/1991	Bragg et al.
			5,018,932 A	5/1991	Croisier
	1,526,527 A 2/1925 Butler		5,035,269 A	7/1991	Pytryga et al.
	1,560,826 A 11/1925 Kirschbraun		5,046,856 A	9/1991	McIntire
	1,576,940 A 3/1926 Arthur		5,052,486 A	10/1991	Wilson
	2,073,652 A 3/1937 Robb		5,121,989 A	6/1992	Horton et al.
	2,099,898 A 11/1937 Larkin		5,190,374 A	3/1993	Harms et al.
	2,357,583 A 9/1944 Franco		5,195,861 A	3/1993	Handke
	2,735,839 A 2/1956 Schrenk		5,201,498 A	4/1993	Akins
	2,774,497 A 12/1956 Martin		5,236,261 A	8/1993	Hagenbuch
	2,792,262 A 5/1957 Hathorn		5,339,996 A	8/1994	Dubbert et al.
	2,858,950 A 11/1958 Martin		5,362,193 A	11/1994	Milstead
	3,155,248 A 11/1964 Haller		5,382,411 A	1/1995	Allen
	3,170,560 A 2/1965 Obmascher		5,387,736 A	2/1995	Salomone et al.
	3,208,616 A 9/1965 Haskins		5,413,154 A	5/1995	Hurst, Jr. et al.
	3,263,436 A 8/1966 Goldfarb		5,426,137 A	6/1995	Allen
	3,314,557 A 4/1967 Sackett		5,427,497 A	6/1995	Dillman
	3,378,152 A 4/1968 Warner et al.		5,447,674 A	9/1995	Schellenbach et al.
	3,394,961 A 7/1968 Matte		5,571,281 A	11/1996	Allen
	3,451,986 A 6/1969 Metais		5,667,298 A	9/1997	Musil et al.
	3,490,632 A 1/1970 McKinney		5,685,416 A	11/1997	Bonnet
	3,497,327 A 2/1970 Kehse		5,775,713 A	7/1998	Peterson et al.
	3,560,053 A 2/1971 Orloff		5,777,234 A	7/1998	Kosmal
	3,618,801 A 11/1971 Blanchard		5,785,421 A	7/1998	Milek
	3,666,129 A 5/1972 Haskins		5,795,062 A	8/1998	Johnson
	3,687,319 A 8/1972 Adam et al.		5,822,930 A	10/1998	Klein
	3,743,108 A 7/1973 Visser		5,964,566 A	10/1999	Stewart et al.
	3,756,443 A 9/1973 Verschage et al.		6,000,840 A	12/1999	Paterson et al.
	3,787,479 A 1/1974 Oriehl et al.		6,050,743 A	4/2000	Medinger
	3,842,910 A 10/1974 Zingg et al.		6,186,195 B1	2/2001	Anstotz
	3,883,019 A 5/1975 Hansen, Jr.		6,186,654 B1	2/2001	Gunteret, Jr. et al.
	3,883,148 A 5/1975 Miller		6,193,402 B1	2/2001	Grimland et al.
	3,894,645 A 7/1975 Verschage		6,286,986 B2	9/2001	Grimland et al.
	3,938,673 A 2/1976 Perry, Jr.		6,293,689 B1	9/2001	Guntert, Jr. et al.
	3,974,602 A 8/1976 Pohl et al.		6,474,926 B2	11/2002	Weiss
	3,985,254 A 10/1976 Grandury		6,491,421 B2	12/2002	Rondeau et al.
	3,998,433 A 12/1976 Iwako		6,527,428 B2	3/2003	Guntert, Jr. et al.
	4,026,441 A 5/1977 Jones		6,832,851 B1	12/2004	von Wilcken
	4,077,612 A 3/1978 Ricciardi		6,939,031 B2	9/2005	Pham et al.
	4,079,150 A 3/1978 Beck et al.		6,948,535 B2	9/2005	Stegemoeller
	4,090,623 A 5/1978 Noyon		7,048,432 B2	5/2006	Phillippi et al.
	4,099,005 A 7/1978 Fullington et al.		7,104,328 B2	9/2006	Phillippi et al.
	4,103,793 A 8/1978 Weaver		7,214,028 B2	5/2007	Boasso et al.
	4,111,314 A 9/1978 Nelson		7,258,522 B2	8/2007	Pham et al.
	4,178,117 A 12/1979 Brugler		7,308,953 B2	12/2007	Bames
	4,187,047 A 2/1980 Squifflet, Sr.		7,419,296 B2	9/2008	Allen
	4,209,278 A 6/1980 Cooper et al.		7,424,943 B2	9/2008	Gausman et al.
	4,222,498 A 9/1980 Brock		7,540,308 B2	6/2009	Pessin et al.
	4,248,359 A 2/1981 Brock		7,614,451 B2	11/2009	Blaschke et al.
	4,249,848 A 2/1981 Griffin et al.				

(56)

References Cited

U.S. PATENT DOCUMENTS

7,703,518 B2 4/2010 Phillippi et al.  
 7,815,222 B2 10/2010 Markham  
 7,836,949 B2 11/2010 Dykstra  
 7,837,427 B2 11/2010 Beckel et al.  
 7,841,394 B2 11/2010 McNeel et al.  
 7,845,413 B2 12/2010 Shampine et al.  
 7,866,881 B2 1/2011 El Kholy et al.  
 7,921,914 B2 4/2011 Bruins et al.  
 7,926,564 B2 4/2011 Phillippi et al.  
 7,931,088 B2 4/2011 Stegemoeller et al.  
 8,066,955 B2 11/2011 Pinchot  
 8,083,083 B1 12/2011 Mohns  
 8,127,844 B2 3/2012 Luharuka et al.  
 8,137,051 B2 3/2012 Glenn et al.  
 8,142,134 B2 3/2012 Lavoie et al.  
 8,146,665 B2 4/2012 Neal  
 8,313,269 B2 11/2012 Fisher et al.  
 8,354,602 B2 1/2013 Lucas et al.  
 8,585,341 B1 11/2013 Oren et al.  
 8,651,792 B2 2/2014 Friesen  
 8,661,743 B2 3/2014 Flusche  
 8,726,584 B1 5/2014 Nolte et al.  
 8,734,081 B2 5/2014 Stegemoeller et al.  
 8,834,012 B2 9/2014 Case et al.  
 8,926,252 B2 1/2015 McIver et al.  
 8,931,996 B2 1/2015 Friesen et al.  
 8,944,740 B2 2/2015 Teichrob et al.  
 9,017,001 B1 4/2015 Dueck  
 9,097,033 B2 8/2015 Margevicius et al.  
 9,457,335 B2 10/2016 Pham et al.  
 9,475,029 B2 10/2016 McSpadden et al.  
 9,663,303 B2 5/2017 Waldner et al.  
 9,688,178 B2 6/2017 Pham  
 2002/0034120 A1 3/2002 Guntert, Jr. et al.  
 2002/0147370 A1 10/2002 Hinz et al.  
 2003/0150494 A1\* 8/2003 Morgan ..... B01F 3/0861  
 137/574  
 2003/0161212 A1 8/2003 Neal et al.  
 2003/0196809 A1 10/2003 Willberg et al.  
 2003/0202869 A1 10/2003 Posch  
 2003/0227817 A1 12/2003 Martel et al.  
 2004/0008571 A1\* 1/2004 Goody ..... B01F 3/1221  
 366/154.1  
 2004/0209780 A1 10/2004 Harris et al.  
 2004/0256106 A1 12/2004 Phillippi et al.  
 2005/0028979 A1 2/2005 Brannon et al.  
 2005/0067351 A1 3/2005 Graham  
 2005/0091941 A1 5/2005 Baird  
 2005/0123385 A1 6/2005 Kirsch  
 2005/0201197 A1 9/2005 Duell et al.  
 2006/0028914 A1 2/2006 Phillippi et al.  
 2006/0065400 A1 3/2006 Smith  
 2006/0107998 A1\* 5/2006 Kholy ..... B01F 3/1271  
 137/3  
 2006/0289166 A1 12/2006 Stromquist et al.  
 2007/0014653 A1 1/2007 Glenn et al.  
 2007/0114035 A1 5/2007 Parris et al.  
 2007/0179326 A1 8/2007 Baker  
 2007/0201305 A1 8/2007 Heilman et al.  
 2008/0008562 A1 1/2008 Beckel et al.  
 2008/0066911 A1 3/2008 Luharuka et al.  
 2008/0073895 A1 3/2008 Herman et al.  
 2008/0179054 A1 7/2008 McGough et al.  
 2008/0264641 A1 10/2008 Slabaugh et al.  
 2009/0078410 A1 3/2009 Krenek et al.  
 2009/0078792 A1 3/2009 Vlasak  
 2009/0090504 A1\* 4/2009 Weightman ..... G01N 11/04  
 166/250.01  
 2010/0038077 A1 2/2010 Heilman et al.  
 2010/0071284 A1 3/2010 Hagan et al.  
 2010/0188926 A1 7/2010 Stegemoeller et al.  
 2010/0243251 A1 9/2010 Luharuka et al.  
 2010/0243252 A1 9/2010 Luharuka et al.  
 2010/0243255 A1 9/2010 Luharuka et al.  
 2010/0278621 A1 11/2010 Redekop

2010/0319921 A1 12/2010 Eia et al.  
 2010/0329072 A1 12/2010 Hagan et al.  
 2011/0003720 A1 1/2011 Sullivan  
 2011/0061855 A1 3/2011 Case et al.  
 2011/0063942 A1 3/2011 Hagan et al.  
 2011/0127178 A1 6/2011 Claussen  
 2011/0197536 A1 8/2011 Clark  
 2012/0024738 A1 2/2012 Herman et al.  
 2012/0048537 A1 3/2012 Rettie et al.  
 2012/0127820 A1 5/2012 Noles, Jr.  
 2012/0127822 A1\* 5/2012 Noles, Jr. .... B01F 5/0647  
 366/152.2  
 2012/0128449 A1 5/2012 Fikes et al.  
 2012/0134772 A1 5/2012 Herman et al.  
 2012/0167485 A1 7/2012 Trevithick et al.  
 2012/0219391 A1 8/2012 Teichrob et al.  
 2012/0255734 A1 10/2012 Coli et al.  
 2012/0273206 A1 11/2012 Zamora et al.  
 2012/0298210 A1 11/2012 Pham et al.  
 2013/0105166 A1 5/2013 Medvedev et al.  
 2013/0150268 A1 6/2013 Oldham  
 2013/0269735 A1 10/2013 Roetzel et al.  
 2013/0288934 A1 10/2013 Powell et al.  
 2013/0309052 A1 11/2013 Luharuka et al.  
 2013/0324444 A1 12/2013 Lesko et al.  
 2014/0041317 A1 2/2014 Pham et al.  
 2014/0041319 A1 2/2014 Pham et al.  
 2014/0041322 A1 2/2014 Pham et al.  
 2014/0044508 A1 2/2014 Luharuka et al.  
 2014/0166647 A1 6/2014 Sheesley et al.  
 2014/0255265 A1 9/2014 Kulkarni et al.  
 2014/0364346 A1\* 12/2014 Weinstein ..... C09K 8/90  
 507/225  
 2015/0044003 A1 2/2015 Pham  
 2015/0044004 A1 2/2015 Pham et al.  
 2015/0064077 A1 3/2015 McSpadden et al.  
 2015/0166260 A1 6/2015 Pham et al.  
 2015/0238912 A1 8/2015 Luharuka et al.  
 2015/0238913 A1 8/2015 Luharuka et al.  
 2015/0238914 A1 8/2015 Luharuka et al.  
 2015/0240148 A1 8/2015 Luharuka et al.  
 2016/0129418 A1 5/2016 Pham et al.  
 2016/0130924 A1 5/2016 Pham et al.  
 2017/0327309 A1 11/2017 Hunter et al.

FOREIGN PATENT DOCUMENTS

CN 2693601 Y 4/2005  
 CN 101434836 A 5/2009  
 CN 201317413 Y 9/2009  
 CN 201458370 U 5/2010  
 CN 201610285 U 10/2010  
 CN 202398329 U 8/2012  
 CN 202506322 U 10/2012  
 CN 203486442 U 3/2014  
 CN 103721619 A 4/2014  
 CN 204109871 U 1/2015  
 EP 0048312 3/1982  
 EP 0048312 A1 3/1982  
 EP 0241056 10/1987  
 EP 0241056 A1 10/1987  
 EP 2609999 7/2013  
 EP 2609999 A1 7/2013  
 FR 2655007 A1 5/1991  
 JP S5715828 1/1982  
 JP S5715828 A 1/1982  
 KR 100589613 B1 6/2006  
 RU 10418 U1 7/1999  
 RU 2228842 C2 1/2004  
 SU 1341161 A1 9/1987  
 WO 8500046 A1 1/1985  
 WO 1985000046 1/1985  
 WO 2002044517 A1 6/2002  
 WO 03087182 A2 10/2003  
 WO 2007022300 A2 2/2007  
 WO 2007098606 A1 9/2007  
 WO 2010070599 A1 6/2010  
 WO 2011061503 A1 5/2011  
 WO 2011088493 A1 7/2011

(56)

**References Cited**

## FOREIGN PATENT DOCUMENTS

WO	2012121896	A2	9/2012
WO	2012166590	A1	12/2012
WO	2013099826		7/2013
WO	2013099826	A1	7/2013
WO	2013134624	A1	9/2013
WO	2014028317	A1	2/2014

## OTHER PUBLICATIONS

International Search Report and Written Opinion issued in International Application No. PCT/US2015/030287, dated Jul. 29, 2015, 14 pages.

International Search Report and Written Opinion issued in International Application No. PCT/US2015/059177, dated Feb. 17, 2016, 14 pages.

International Search Report and Written Opinion issued in International Application No. PCT/US2015/059182, dated Feb. 29, 2016, 13 pages.

Office Action issued in Eurasian Patent Appl. No. 201691737/31 dated Mar. 19, 2018; 4 pages (with English translation).

Office Action issued in Chinese Patent Appl. No. 201580036796.9 dated Oct. 25, 2018; 29 pages (with English translation).

Office Action issued in Russian Patent Appl. No. 2015117758 dated Dec. 5, 2018; 13 pages (with English translation).

Office Action issued in Russian Patent Appl. No. 2015117770 dated Nov. 16, 2018; 16 pages (with English Translation).

Office Action issued in Russian Patent Application No. 2017102359 dated Mar. 7, 2018; 11 pages.

Office Action issued in Russian Patent Application No. 2014132435 dated Apr. 3, 2018; 9 pages.

Decision on Grant issued in Russian Patent Appl. No. 2017102359 dated Jul. 27, 2018; 15 pages (with English translation).

Office Action issued in Chinese Patent Appl. No. 201580034894.9 dated Jul. 3, 2018; 9 pages (with English translation).

Decision on Grant issued in Russian Patent Appl. No. 2014132435 dated Sep. 20, 2018; 23 pages (with English translation).

Natural gas flow measurement, written and compiled by LONG Yangming, Petroleum Industry Press, pp. 84-85, Mar. 1962.

Fracturing technology for ultra-low permeability reservoirs, written by RAN Xinquan, Petroleum Industry Press, pp. 223-224, Feb. 2012.

Office Action issued in Chinese Patent Appl. No. 201580032114.7 dated Jul. 18, 2018; 15 pages.

Practical Technical Manual for Dairy Product Engineer, edit by Gu Ming, pp. 605-607, China Light Industry Press, Jan. 2009.

Office Action issued in Chinese Patent Appl. No. 2015800109793 dated Sep. 12, 2018; 32 pages (with English translation).

Examination Report dated Dec. 19, 2018 in corresponding AU Application No. 2015259393; 4 pages.

“Practical Technical Manual for Dairy Product Engineer”, Gu Ming editor, China Light Industry Press, Jan. 2009, pp. 605-607.

Office Action issued in Canadian Patent Application No. 2948002 dated May 31, 2021, 3 pages.

Office Action issued in U.S. Appl. No. 16/859,188 dated Sep. 27, 2021, 54 pages.

Exam Report issued in Australian Patent Application No. 2019283869 dated Oct. 15, 2021, 2 pages.

Examiner’s Report issued in Canadian Patent Application No. 2858452 dated Oct. 25, 2021, 4 pages.

Office Action 97624 issued in Mexican Patent Application No. MX/a/2016/014601 dated Oct. 22, 2021, 7 pages.

Extended Search Report issued in European Patent Appl. No. 15755550.9 dated Oct. 9, 2017; 8 pages.

Substantive Examination issued in Bahrain Patent Application No. 20160114 dated Jan. 10, 2022, 10 pages with English translation.

Office Action issued in U.S. Appl. No. 16/859,188 dated Jan. 18, 2022, 12 pages.

Office Action issued in U.S. Appl. No. 14/192,838 dated Jan. 20, 2022, 13 pages.

Examination Report issued in Australian patent application 2015259397 dated Mar. 15, 2019, 4 pages.

Examination Report issued in Canadian patent application 2948619 dated Jul. 9, 2021, 4 pages.

International Preliminary Report on Patentability issued in International Patent Application PCT/US2015/030294 dated Nov. 15, 2016, 6 pages.

International Search Report and Written Opinion issued in International Patent Application PCT/US2015/030294 dated Jul. 24, 2015, 8 pages.

International Preliminary Report on Patentability issued in International Patent Application PCT/US2015/030287 dated Nov. 15, 2016, 12 pages.

Exam Report issued in UAE patent application P935/2016 dated Jan. 31, 2021, 7 pages.

First office action and search report issued in Chinese patent application 21410566169.3 dated Apr. 26, 2016, 10 pages.

Office Action 36176 issued in Mexican patent application MX/a/2014/009520 dated May 8, 2017, 7 pages.

Office Action 97253 issued in Mexican patent application MX/a/2014/009520 dated Dec. 5, 2017, 6 pages.

Office Action 37974 issued in Mexican patent application MX/a/2014/009520 dated May 11, 2018, 6 pages.

Office Action 86561 issued in Mexican patent application MX/a/2014/009520 dated Oct. 18, 2018, 5 pages.

First Examination Report issued in Australian patent application 2013302969 dated Dec. 8, 2016, 5 pages.

Office Action issued in Russian patent application 2015108765 dated Sep. 8, 2016. No translation available. 4 pages.

Decision on Grant issued in Russian Patent Application 2015108762 dated Oct. 9, 2017 with translation. 15 pages.

International Search Report and Written Opinion issued in International Patent Application PCT/US2013/054287 dated Oct. 24, 2016, 11 pages.

International Preliminary Report on Patentability issued in International Patent Application PCT/US2013/054287 dated Feb. 17, 2015, 7 pages.

Examination report dated Aug. 3, 2016 in corresponding AU Application No. 2013302971; 3 pages.

First office action and search report issued in Chinese patent application 201380048297.2 dated Feb. 1, 2016, 12 pages.

Second office action and search report issued in Chinese patent application 201380048297.2 dated Sep. 23, 2016, 17 pages.

First Examination Report issued in Saudi Arabian patent application 515360032 dated Nov. 21, 2016. No translation. 9 pages.

Second Examination Report issued in Saudi Arabian patent application 515360032 dated Oct. 9, 2017. No translation. 6 pages.

International Search Report and Written Opinion issued in International Patent Application PCT/US2013/054294 dated Oct. 24, 2013, 10 pages.

International Preliminary Report on Patentability issued in International Patent Application PCT/US2013/054294 dated Feb. 17, 2015, 6 pages.

Office Action issued in Algerian patent application 170053 dated Jan. 22, 2018. No Translation. 1 page.

International Search Report and Written Opinion issued in International Patent Application PCT/US2015/037569 dated Sep. 24, 2015, 17 pages.

International Preliminary Report on Patentability issued in International Patent Application PCT/US2015/037569 dated Dec. 27, 2016, 15 pages.

Notice of Acceptance issued in Australian patent application 2019283869 dated Jan. 21, 2022, 3 pages.

Examination Report dated Feb. 28, 2022 in corresponding Saudi Arabia Application No. 516380275; 7 pages (with English translation).

Re-examination report issued in Chinese Patent Application No. 201580036796.9 dated Mar. 30, 2022; 18 pages.

Substantive Examination issued in Bahrain Patent Application No. 20160114 dated Apr. 25, 2022, 9 pages with English translation.

(56)

**References Cited**

OTHER PUBLICATIONS

Office Action issued in U.S. Appl. No. 16/859,188 dated May 3, 2022, 16 pages.

\* cited by examiner

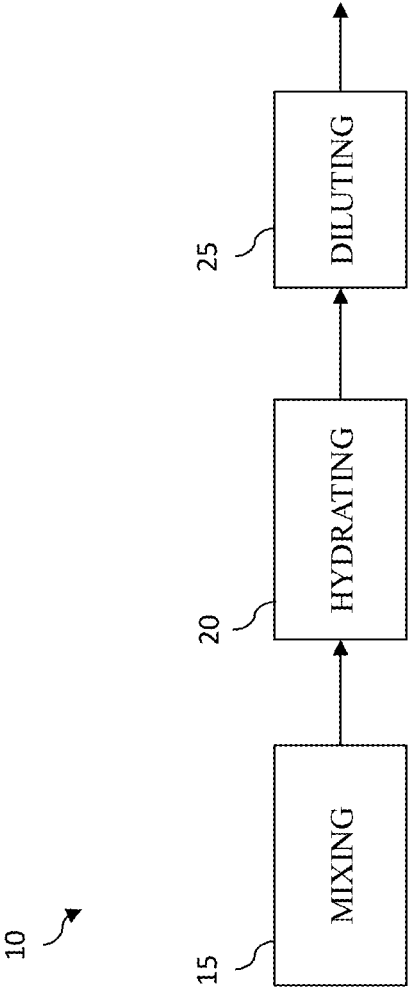


FIG. 1

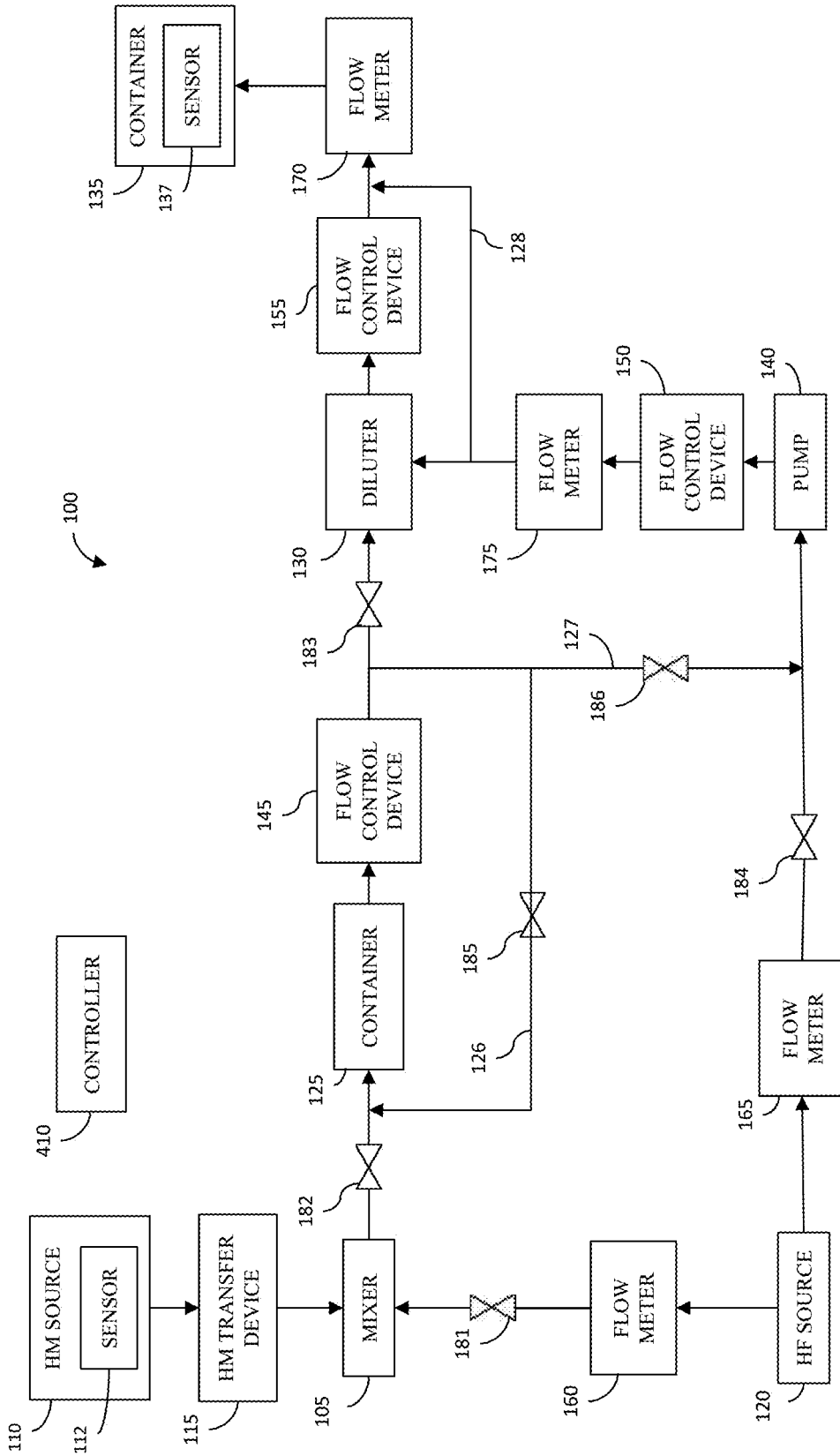


FIG. 2

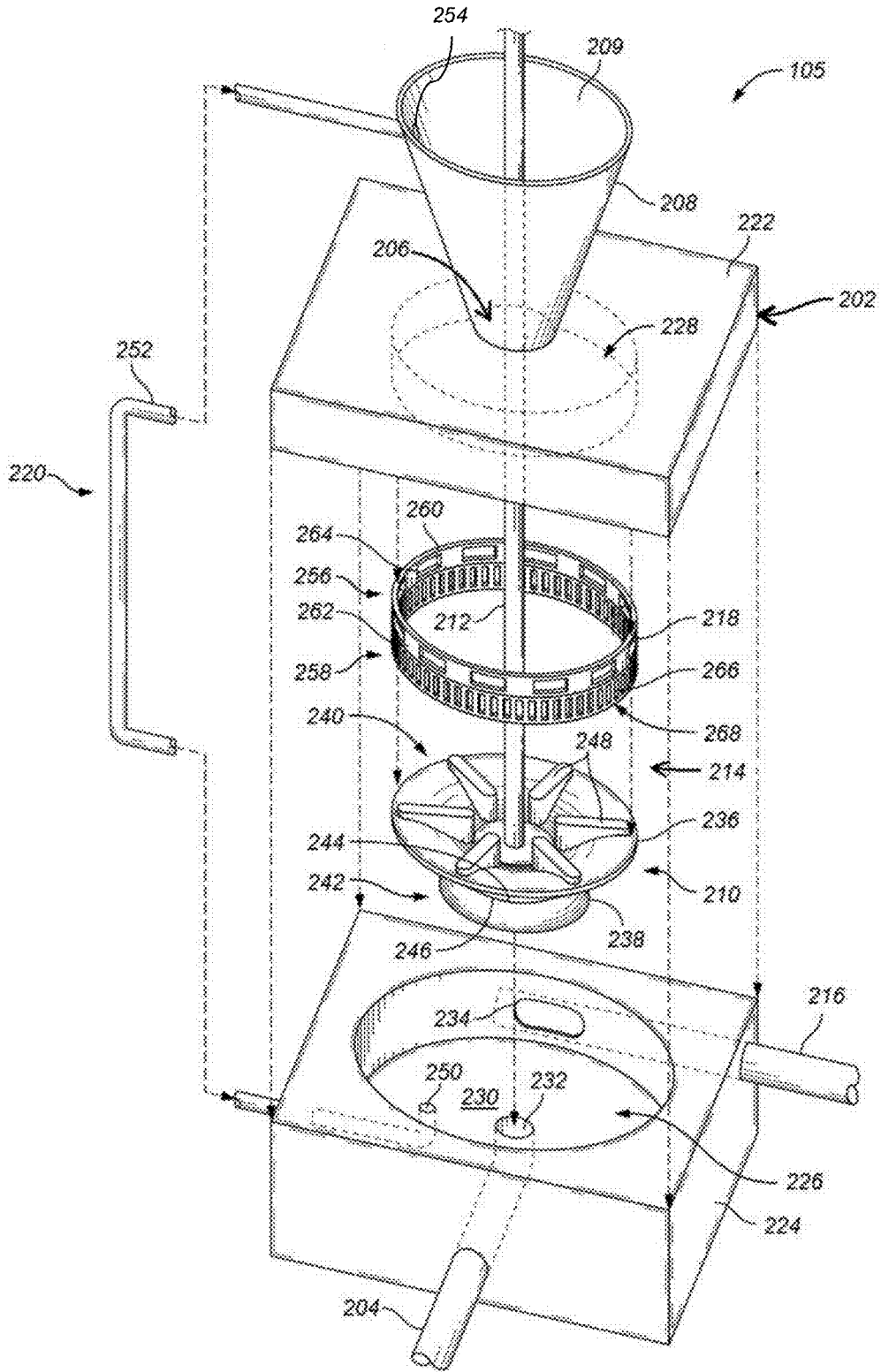


FIG. 3



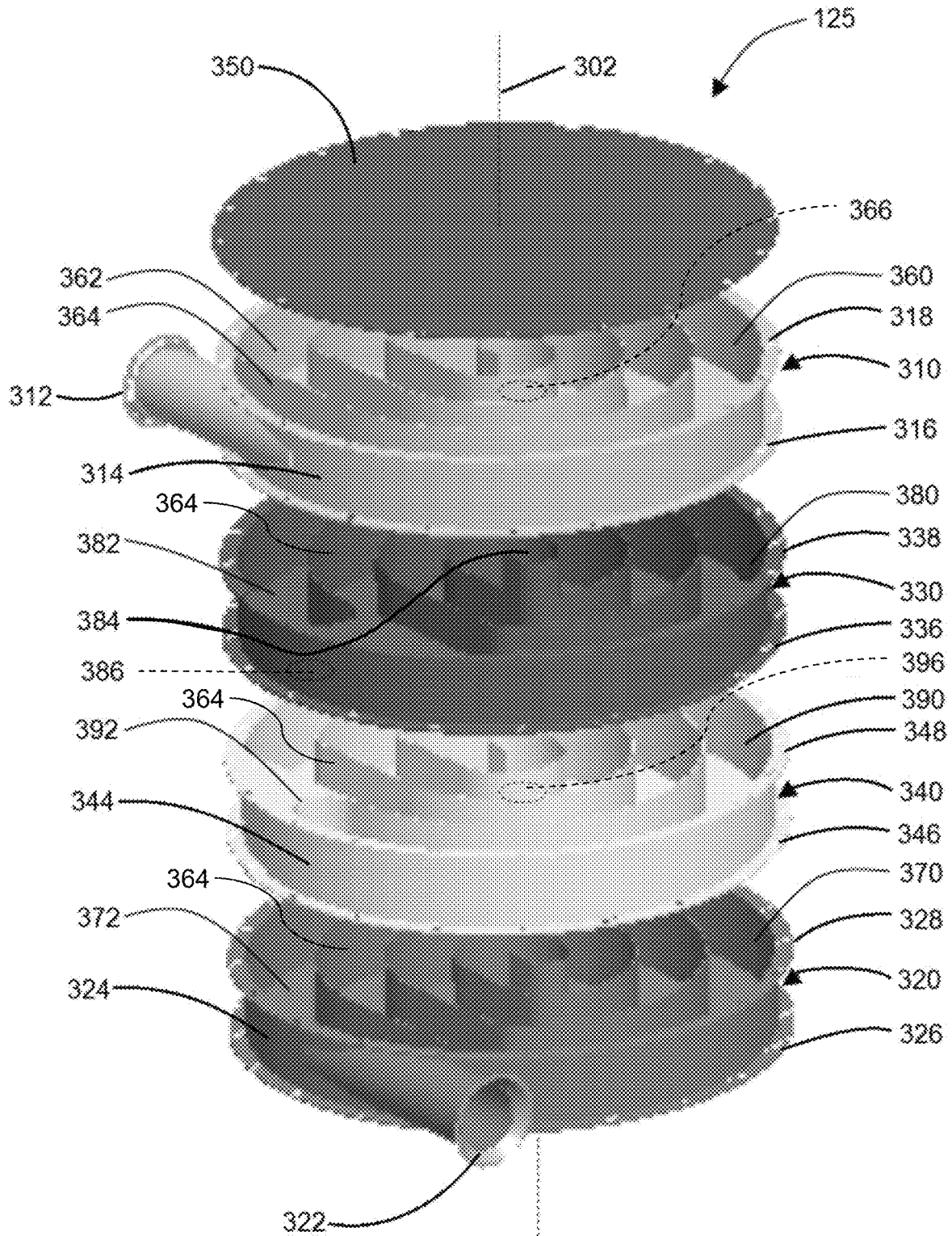


FIG. 4

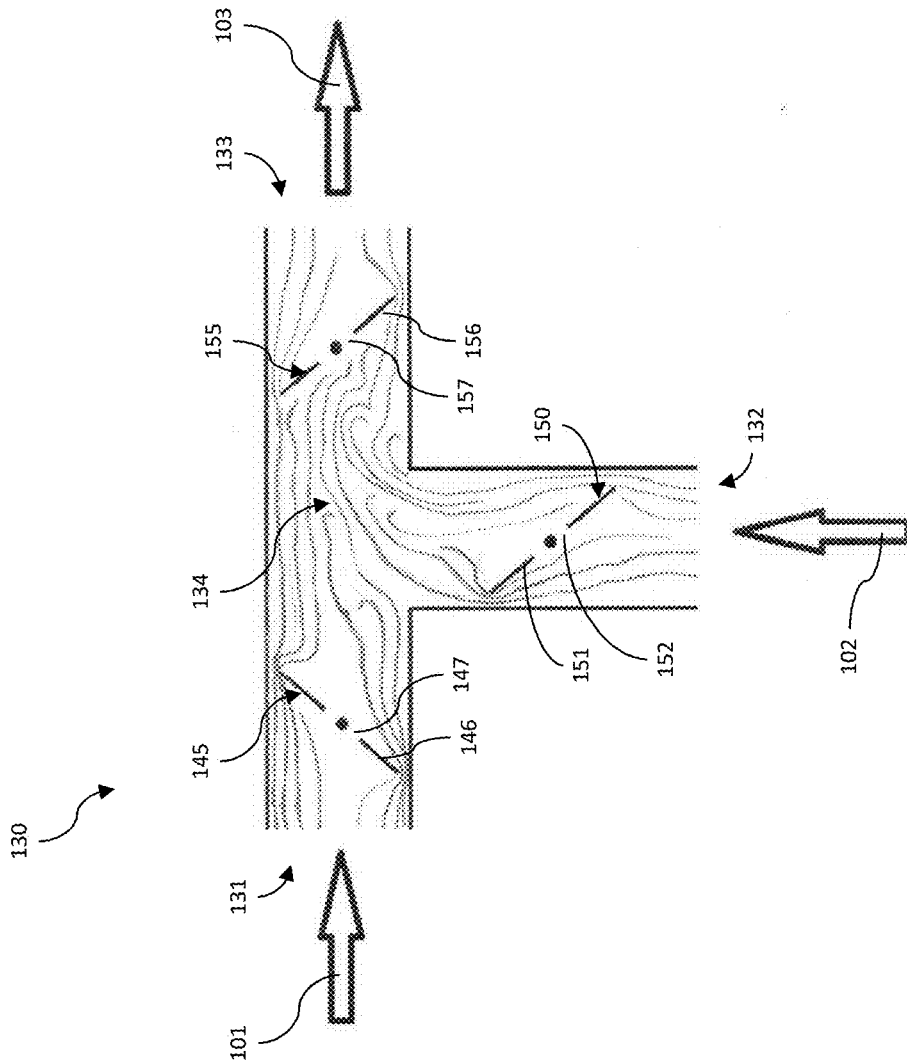


FIG. 5

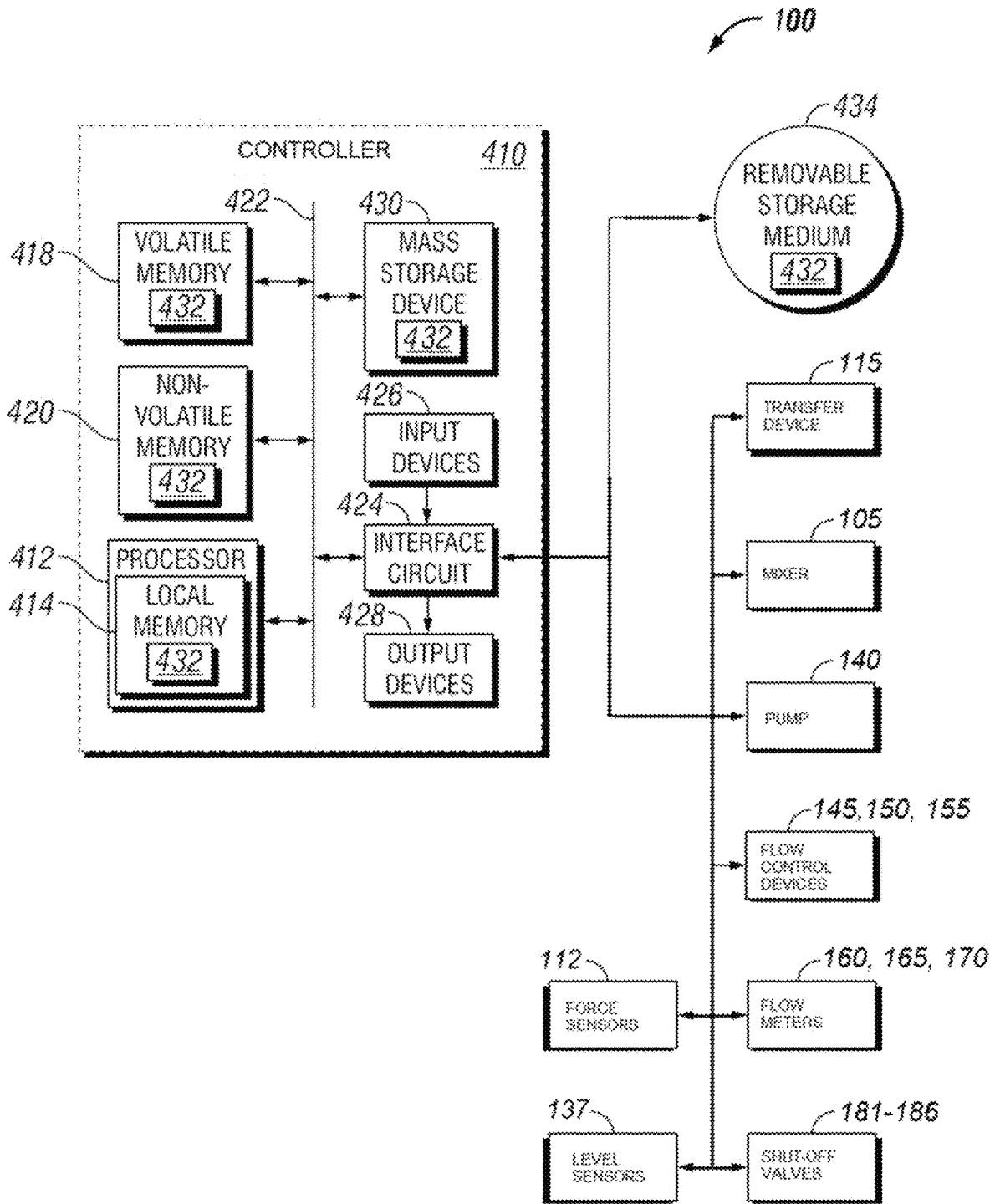


FIG. 6

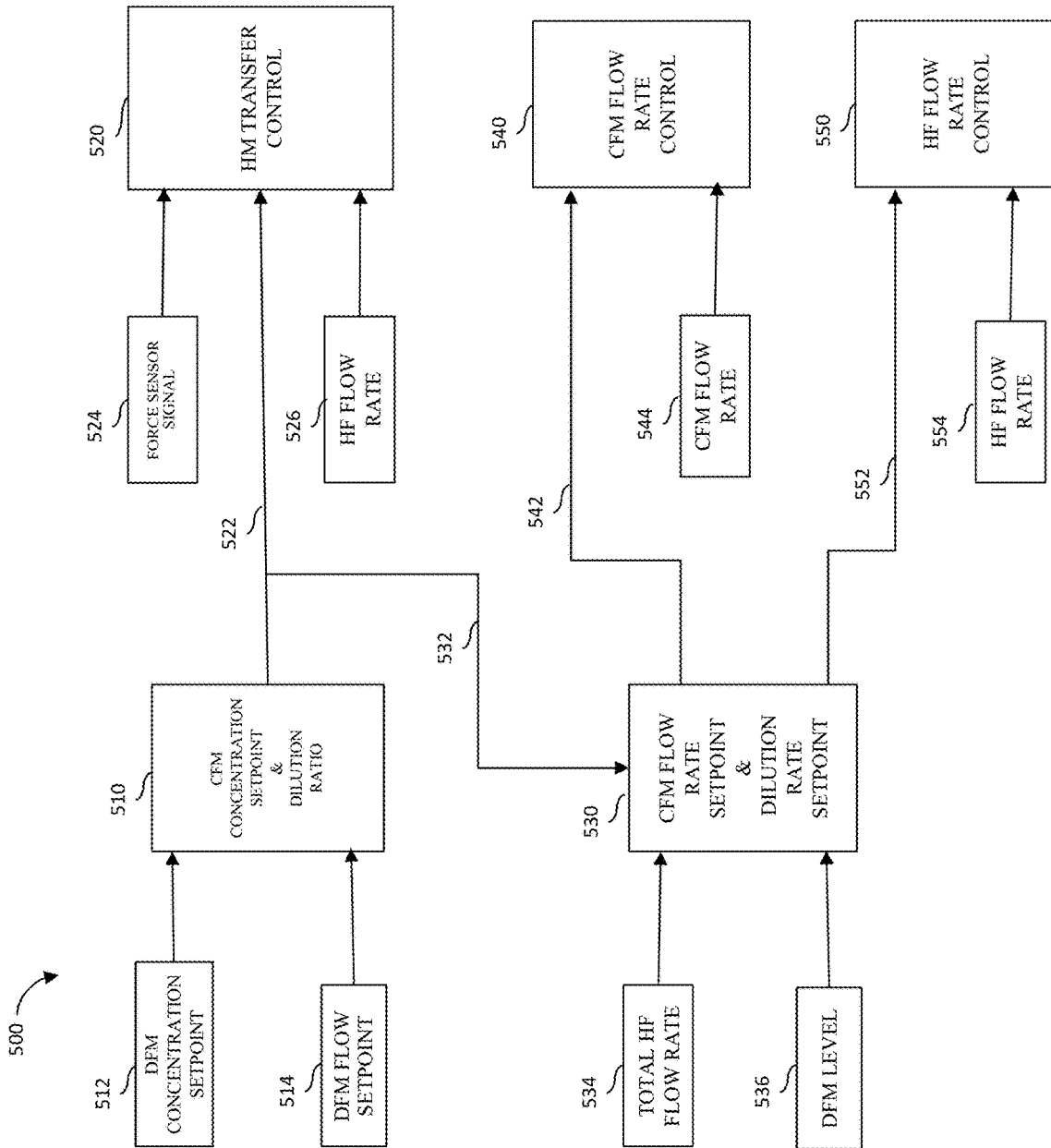


FIG. 7

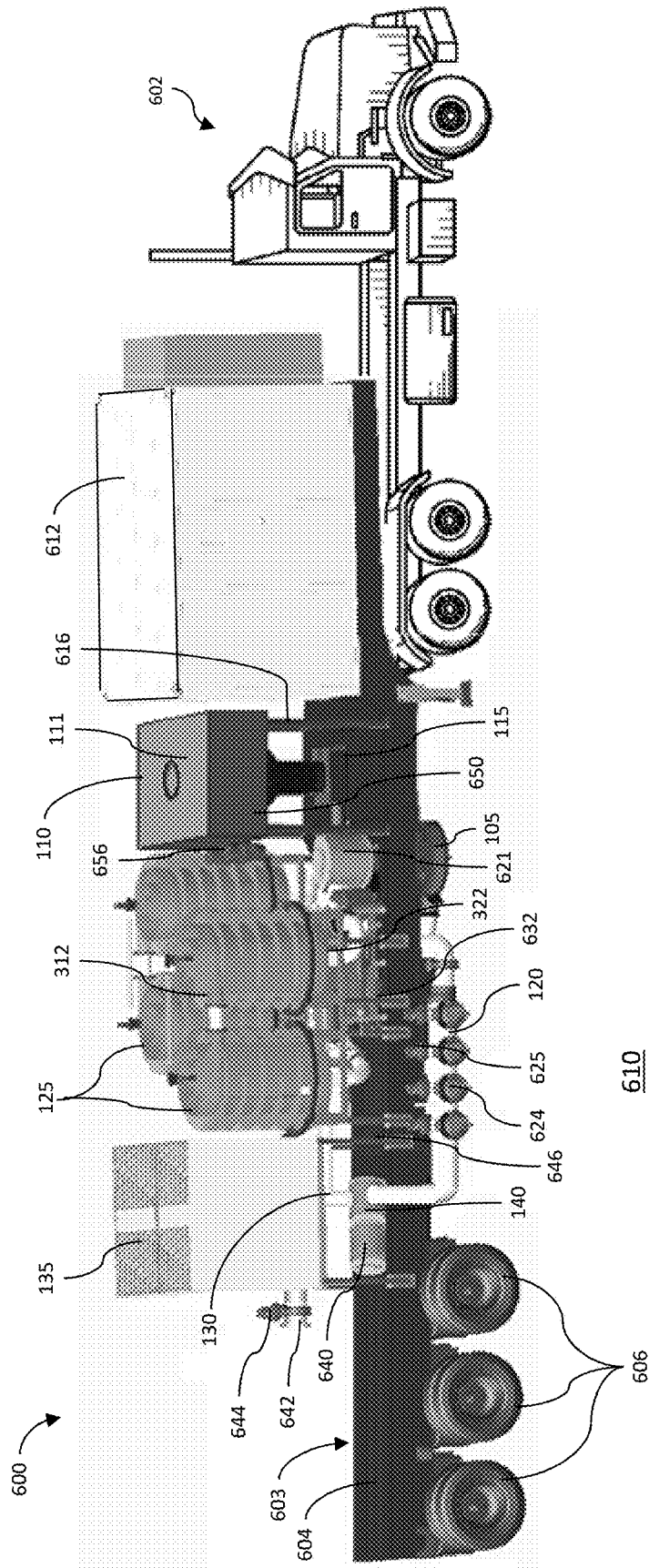


FIG. 8

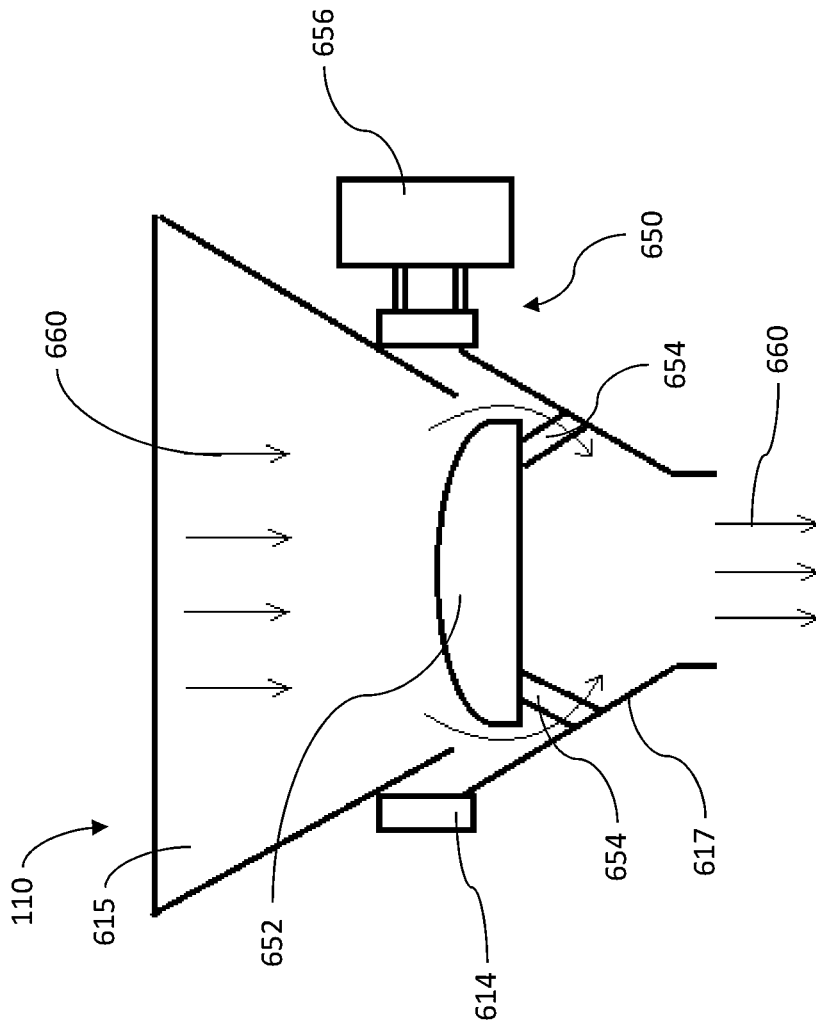


FIG. 9

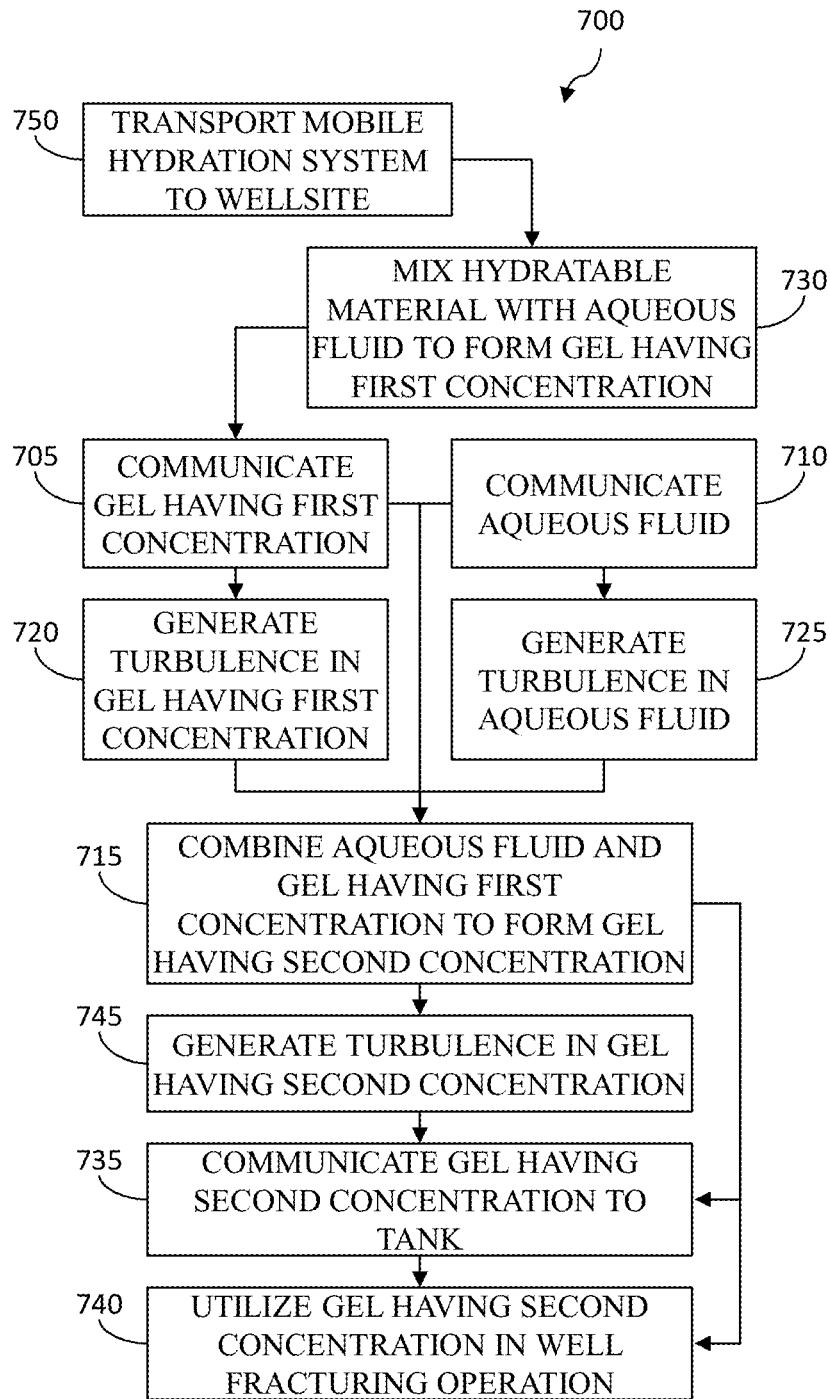


FIG. 10

**HYDRATION SYSTEMS AND METHODS****CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims priority to and the benefit of U.S. Provisional Application No. 61/991,685 entitled "Continuous Gel Mixing Apparatus and Method," filed May 12, 2014, the entire disclosure of which is hereby incorporated herein by reference.

This application is also a continuation-in-part of U.S. application Ser. No. 14/192,838 entitled "Mixing Apparatus with Stator and Method," filed Feb. 27, 2014, the entire disclosure of which is hereby incorporated herein by reference.

This application is also a continuation-in-part of U.S. application Ser. No. 14/536,415, entitled "Hydration Apparatus and Method," filed Nov. 7, 2014, the entire disclosure of which is hereby incorporated herein by reference.

**BACKGROUND OF THE DISCLOSURE**

High viscosity fluid mixtures or gels comprising hydratable material and/or additives mixed with water and/or other hydrating fluid are utilized in fracturing and other subterranean well treatment operations. These high viscosity fluid mixtures are formulated at the wellsite or transported to the wellsite from a remote location. Hydration is a process by which the hydratable material solvates, absorbs, and/or otherwise reacts with hydrating fluid to create the high viscosity fluid mixture. The level of hydration of the hydratable material may be increased by maintaining the hydratable material in the hydrating fluid during a process step referred to as residence time, such as may take place in one or more hydration tanks.

Hydration and the associated increase in viscosity take place over a time span corresponding to the residence time of the hydratable material in the hydrating fluid. Hence, the rate of hydration of the hydratable material is a factor in the hydration operations, and particularly scrutinized in continuous hydration operations by which the high viscosity fluid mixture is continuously produced at the job site during the course of wellsite operations. To achieve sufficient hydration and/or viscosity, long tanks or a series of large tanks are utilized to provide the hydratable material with sufficient volume and, thus, residence time in the hydrating fluid. Such tanks are transported to or near the wellsite. For example, the hydratable material may be mixed with the hydrating fluid before being introduced into a series of tanks and, as the fluid mixture passes through the series of tanks, the hydratable material may hydrate to a sufficient degree.

A typical gravity-flow hydration tank cannot handle high concentration fluid mixture. Therefore, other tanks having large volumes are utilized to sufficiently dilute the fluid mixture to a sufficiently low viscosity to permit the fluid mixture to pass through the gravity-flow hydration tank. Hydration tanks having large volumes comprise large footprints, are difficult to transport, and/or may not be transportable.

**SUMMARY OF THE DISCLOSURE**

This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify indis-

pensable features of the claimed subject matter, nor is it intended for use as an aid in limiting the scope of the claimed subject matter.

The present disclosure introduces a method that includes communicating a substantially continuous stream of gel having a first concentration, communicating a substantially continuous stream of aqueous fluid, and combining the substantially continuous streams of gel having the first concentration and aqueous fluid to form a substantially continuous stream of gel having a second concentration. The second concentration is substantially lower than the first concentration. The method may also include utilizing the gel having the second concentration in a well fracturing operation.

The present disclosure also introduces a method that includes substantially continuously feeding hydratable material and hydrating fluid into a mixer, and substantially continuously operating the mixer to mix the hydratable material and the hydrating fluid to form a first substantially continuous stream. The first substantially continuous stream includes gel having a first concentration of hydratable material and a first viscosity. The method also includes substantially continuously communicating the first substantially continuous stream through an enclosed hydrator to form a second substantially continuous stream. The second substantially continuous stream includes gel having the first concentration of hydratable material and a second viscosity that is substantially greater than the first viscosity. The method also includes substantially continuously combining the second substantially continuous stream and a third substantially continuous stream to form a fourth substantially continuous stream. The third substantially continuous stream substantially includes aqueous fluid. The fourth substantially continuous stream includes gel having a second concentration of hydratable material that is substantially less than the first concentration. The method also includes utilizing gel from the fourth substantially continuous stream in a well fracturing operation.

The present disclosure also introduces an apparatus that includes a system operable to form a substantially continuous supply of gel having a first hydratable material concentration for use in a well fracturing operation. The system includes a mixer to receive and mix hydratable material and aqueous fluid to form a substantially continuous supply of gel having a second hydratable material concentration. The second hydratable material concentration is substantially higher than the first hydratable material concentration. The system also includes an enclosed tank having an internal flow path traversed by the substantially continuous supply of gel having the second hydratable material concentration during a period of time sufficient to permit a viscosity of the substantially continuous supply of gel having the second hydratable material concentration to increase to a predetermined level. The system also includes a diluter operable to dilute the substantially continuous supply of increased viscosity gel having the second hydratable material concentration to substantially continuously supply gel having the first hydratable material concentration.

These and additional aspects of the present disclosure are set forth in the description that follows, and/or may be learned by a person having ordinary skill in the art by reading the materials herein and/or practicing the principles described herein. At least some aspects of the present disclosure may be achieved via means recited in the attached claims.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The present disclosure is understood from the following detailed description when read with the accompanying fig-



ures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIG. 1 is a flow-chart diagram of at least a portion of an example implementation of a method according to one or more aspects of the present disclosure.

FIG. 2 is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. 3 is an expanded view of an example implementation of a portion of the apparatus shown in FIG. 2 according to one or more aspects of the present disclosure.

FIG. 4 is an expanded view of an example implementation of a portion of the apparatus shown in FIG. 2 according to one or more aspects of the present disclosure.

FIG. 5 is a schematic view of an example implementation of a portion of the apparatus shown in FIG. 2 according to one or more aspects of the present disclosure.

FIG. 6 is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. 7 is a flow-chart diagram of at least a portion of an example implementation of a method according to one or more aspects of the present disclosure.

FIG. 8 is a perspective view of an example implementation of the apparatus shown in FIG. 2 according to one or more aspects of the present disclosure.

FIG. 9 is a schematic view of an example implementation of a portion of the apparatus shown in FIG. 8 according to one or more aspects of the present disclosure.

FIG. 10 is a flow-chart diagram of at least a portion of an example implementation of a method according to one or more aspects of the present disclosure.

#### DETAILED DESCRIPTION

It is to be understood that the following disclosure provides many different implementations, or examples, for implementing different features of various implementations. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for simplicity and clarity, and does not in itself dictate a relationship between the various implementations and/or configurations discussed. Moreover, the formation of a first feature over or on a second feature in the description that follows may include implementations in which the first and second features are formed in direct contact, and may also include implementations in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

FIG. 1 is a schematic view of at least a portion of an example implementation of a method (10) for forming a fluid mixture according to one or more aspects of the present disclosure. The resulting fluid mixture may also be referred to herein as a gel.

The method (10) comprises mixing (15) a hydratable material with a hydrating fluid within a mixer at a predetermined ratio to form the fluid mixture having a first concentration of hydratable material within the hydrating fluid. Thereafter, the hydratable material is hydrated (20) within a container until a predetermined viscosity or level of hydration is reached. The hydration (20) and the associated

increase in viscosity take place over a period of time during which the hydratable material is in the hydrating fluid. The hydrated (20) fluid mixture is then diluted (25) to achieve a second concentration of hydratable material within the hydrating fluid, such that the second concentration existing after the dilution (25) is substantially less than the first concentration existing after the mixing (15) and hydrating (20). The diluted (25) fluid mixture may then be communicated downstream and further processed, such as to form a fracturing fluid.

Therefore, the method (10) includes forming (via the mixing (15) and hydrating (20)) a concentrated fluid mixture having a substantially fixed or otherwise predetermined first concentration of hydratable material, and then diluting (25) the concentrated fluid mixture to form a diluted fluid mixture having a second, lower predetermined concentration of hydratable material. The first and second concentrations, and the flow rates of the fluid mixtures at the first and second concentrations, may be adjusted to meet the downstream demand. Moreover, because the concentrated fluid mixture comprises less volume than the diluted fluid mixture, the method (10) may utilize equipment having a relatively smaller volume and/or footprint than a hydration process that directly forms the diluted fluid mixture in the mixer.

The hydratable material may be or comprise a gelling agent, such as guar, a polymer, a synthetic polymer, a galactomannan, a polysaccharide, a cellulose, a clay, and/or a combination thereof, among other examples, and may be introduced into the mixer in the form of solid particles or liquid concentrate. The hydrating fluid may be or comprise water or an aqueous fluid or solution comprising water, among other examples. The resulting fluid mixture may be or comprise that which is known in the art as a gel or a slurry.

Although the methods and the apparatuses within the scope of the present disclosure describe mixing hydratable material with hydrating fluid to form a gel or slurry, it is to be understood that hydratable material may comprise various rheology modifying materials that are mixed with hydrating or other fluids to form a gel, a slurry, and/or other rheology modified fluids, such as may have high low-shear properties, but that may be shear-thinning, within the scope of the present disclosure. Hydratable material may further comprise rheology modifying materials such as polyacrylamides, fiber, nanoscale particles, dry friction reducers, dimeric and trimeric fatty acids, imidazolines, amides, and/or synthetic polymers, among other example materials that provide high viscosity at low shear rates.

FIG. 2 is a schematic view of at least a portion of an example implementation of a hydration system 100 for forming the fluid mixture via the method (10) shown in FIG. 1 and/or otherwise according to one or more aspects of the present disclosure. The hydration system 100 comprises a mixer 105 operable to receive and mix hydratable material and hydrating fluid. For example, the hydratable material may be mixed with the hydrating fluid at a rate of about 120 pounds of hydratable material per about 1000 pounds of hydrating fluid, thus forming a 120-pound fluid mixture. However, the fluid formed and discharged by the mixer 105 may have between about 80 and about 300 pounds of hydratable material per 1000 gallons of hydrating fluid, among other ratios also within the scope of the present disclosure.

The mixer 105 receives the hydratable material from a hydratable material ("HM") source 110. The hydratable material source 110 may comprise a silo, bin, hopper, and/or another container that may permit storage of the hydratable material so as to provide a substantially continuous supply

5

of the hydratable material to the mixer **105**. A lower portion of the hydratable material source **110** may have a tapered configuration terminating with a gate or other outlet permitting the hydratable material to be gravity fed and/or otherwise substantially continuously transferred into the mixer **105**. The hydratable material may be continuously or intermittently transported to the hydratable material source **110** from another wellsite component, such as in implementations in which the hydratable material is transported to the hydratable material source **110** from a delivery vehicle via one or more conveyors. The hydratable material may also or instead be continuously transported from the delivery vehicle directly to the mixer **105**.

The hydratable material may be metered and/or otherwise transferred to the mixer **105** via a transfer device **115**. For example, if the hydratable material substantially comprises a liquid, the transfer device **115** may comprise a metering pump and/or a metering valve, such as may be operable to control the flow rate at which the hydratable material is introduced into the mixer **105**.

However, if the hydratable material substantially comprises solid particles, the transfer device **115** may comprise a volumetric or mass dry metering device operable to control the volumetric or mass flow rate of the hydratable material fed from the hydratable material source **110** to the mixer **105**. For example, the transfer device **115** may include a metering feeder, a screw feeder, an auger, a conveyor, and the like, and may extend between the hydratable material source **110** and the mixer **105** such that an inlet of the transfer device **115** is positioned generally below the hydratable material source **110** and an outlet is positioned generally above the mixer **105**. A blade extending along a length of the transfer device **115**, for example, may be operatively connected with a motor operable to rotate the blade. As the mixer **105** is operating, the rotating blade may move the hydratable material from the inlet to the outlet, whereby the hydratable material may be dropped, fed, or otherwise introduced into the mixer **105**.

Although not depicted in FIG. **2**, the hydration system **100** may comprise more than one hydratable material source **110** and corresponding transfer devices **115**. For example, the hydration system **100** may comprise a first hydratable material source **110** storing hydratable material that substantially comprises liquid, and a second hydratable material source **110** storing hydratable material that substantially comprises solid particles. In such implementations, the transfer device **115** corresponding to the first hydratable material source **110** may comprise a metering pump and/or a metering valve, and the transfer device **115** corresponding to the second hydratable material source **110** may comprise a volumetric or mass dry metering device.

The hydratable material source **110** may comprise one or more force sensors **112**, such as load cells or other sensors operable to generate information related to the mass or parameter indicative of the quantity of the hydratable material within the hydratable material source **110**. Such information may be utilized to monitor the actual transfer rate of the hydratable material from the hydratable material source **110** into mixer **105**, to monitor the accuracy of the transfer device **115**, and/or to control the transfer rate of the hydratable material discharged from the hydratable material source **110** and/or the transfer device **115** for feeding to the mixer **105**.

The hydrating fluid may be supplied to the mixer **105** from a hydrating fluid (“HF”) source **120**, such as may comprise a receptacle, a storage tank, a reservoir, a conduit, a manifold, and/or other component for storing and/or

6

communicating the hydrating fluid to the mixer **105**. The supplied hydrating fluid may be drawn into the mixer **105** via a suction force generated by an impeller and/or other internal component of the mixer **105**. The suction force may be sufficient to communicate the hydrating fluid from the hydrating fluid source **120** to the mixer **105**. However, communication of the hydrating fluid from the hydrating fluid source **120** to the mixer **105** may instead or also be facilitated by a pump (not shown), such as may be operable to pressurize and/or move the hydrating fluid from the hydrating fluid source **120** to the mixer **105**.

The mixer **105** is operable to mix the hydratable material and the hydrating fluid, and to pressurize the resulting fluid mixture sufficiently to pump the fluid mixture through one or more first containers **125**. FIG. **3** is an expanded view of an example implementation of at least a portion of the mixer **105** according to one or more aspects of the present disclosure. The following description refers to FIGS. **2** and **3**, collectively.

The mixer **105** may include a housing **202**, a fluid inlet **204**, and an additive inlet **206** extending into the housing **202**. The fluid inlet **204** may be fluidly connected with the hydrating fluid source **120** for receiving hydrating fluid therefrom. The additive inlet **206** may generally include an additive-receiving structure **208**, which may be or include a cone, chamber, bowl, hopper, or the like, having an inner surface **209** configured to receive the hydratable material from the hydratable material source **110**, via the transfer device **115**, and direct the hydratable material into the housing **202**. It is to be understood that the hydratable material may be dry, partially dry, crystalized, fluidic, or pelletized, and/or packaged materials, perhaps including a slurry, and/or other materials to be dispersed within and/or otherwise mixed with the hydrating fluid using the mixer **105**. The hydratable material received through the additive inlet **206** may also be pre-wetted, perhaps forming a partial slurry, such as to avoid fisheyes and/or material buildup.

The mixer **105** may further comprise an impeller/slinger assembly **210** driven by a shaft **212**. The housing **202** may define a mixing chamber **214** in communication with the inlets **204**, **206**, and the impeller/slinger assembly **210** may be disposed in the mixing chamber **214**. Rotation of the impeller/slinger assembly **210** may draw the hydrating fluid from the fluid inlet **204**, mix the drawn hydrating fluid with the hydratable material fed from the additive inlet **206** within the mixing chamber **214**, and pump the resulting mixture through the outlet **216**. The outlet **216** may direct the fluid mixture through one or more fluid conduits into the first container **125**.

The shaft **212** may extend upward through the inlet **206** and out of the additive-receiving structure **208** for connection with an electric motor and/or other prime mover (not shown). The shaft **212** may be connected with the impeller/slinger assembly **210** such that rotation of the shaft **212** rotates the impeller/slinger assembly **210** within the mixing chamber **214**.

The mixer **105** may also include a stator **218** disposed around the impeller/stator assembly **210**. The stator **218** may be in the form of a ring or arcuate portion, example details of which are described below.

The mixer **105** may further comprise a flush line **220** fluidly connected between the additive-receiving structure **208** and an area of the mixing chamber **214** that is proximal to the impeller/slinger assembly **210**. The flush line **220** may tap the hydrating fluid from the mixing chamber **214** at an area of relatively high pressure and deliver it to the inner wall of the additive-receiving structure **208**, which may be

at a reduced (e.g., ambient) pressure. In addition to being at the relatively high pressure, the hydrating fluid tapped by the flush line 220 may be relatively “clean” (i.e., relatively low additives content, as will be described below), such as to pre-wet the additive-receiving structure 208 and promote the avoidance of clumping of the hydratable material being fed into the mixer 105. The flush line 220 may provide the pre-wetting fluid without utilizing additional pumping devices (apart from the pumping provided by the impeller/slinger assembly 210) or additional sources of hydrating fluid or lines from the hydrating fluid source 120. One or more pumps may be provided in addition to or in lieu of tapping the hydrating fluid from the mixing chamber 214.

The housing 202 may comprise an upper housing portion 222 and a lower housing portion 224. Connection of the upper and lower housing portions 222, 224 may define the mixing chamber 214 therebetween. The lower housing portion 224 may define a lower mixing area 226, and the upper housing portion 222 may define an upper mixing area 228 (shown in phantom lines) that may be substantially aligned with the lower mixing area 226. The mixing areas 226, 228 may together define the mixing chamber 214 in which the impeller/slinger assembly 210 and the stator 218 may be disposed. The lower housing portion 224 may also include an interior surface 230 defining the bottom of the lower mixing area 226.

The upper housing portion 222 may be connected with the additive-receiving structure 208, and may provide the additive inlet 206. The lower housing portion 224 may include the fluid inlet 204, which may extend through the lower housing portion 224 to a generally centrally disposed opening 232. The opening 232 may be defined in the interior surface 230. The outlet 216 may extend to an opening 234 communicating with the lower mixing area 226.

The impeller/slinger assembly 210 may include a slinger 236 and an impeller 238. The slinger 236 and the impeller 238 may have inlet faces 240, 242, respectively, and backs 244, 246, respectively. The inlet faces 240, 242 may be each be open (as shown) or at least partially covered by a shroud (not shown), which may form an inlet in the radial inner part of the slinger 236 and/or impeller 238. The backs 244, 246 may be disposed proximal to one another and connected together, such that, for example, the impeller 238 and the slinger 236 may be disposed in a “back-to-back” configuration. Thus, the inlet face 240 of the slinger 236 may face the additive inlet 206, while the inlet face 242 of the impeller 238 may face the fluid inlet 204. Accordingly, the inlet face 242 of the impeller 238 may face the interior surface 230, and the opening 232 defined on the interior surface 230 may be aligned with a radially central portion of the impeller 238.

The slinger 236 may substantially define a saucer-shape generally having a flatter (or flat) middle portion with arcuate or slanted sides, collectively forming at least a portion of the inlet face 240. The sides may be formed, for example, as similar to or as part of a torus that extends around the middle of the slinger 236. The slinger 236 may also be bowl-shaped (e.g., generally a portion of a sphere). The slinger 236 includes six slinger blades 248 on the inlet face 240, although other numbers of blades 248 are also within the scope of the present disclosure. The blades 248 may extend radially in a substantially straight or curved manner. As the slinger 236 rotates, the hydratable material received from the inlet 206 is propelled radially outward, by interaction with the blades 248, and axially upward, as influenced by the shape of the inlet face 240.

Although obscured from view in FIG. 3, the impeller 238 may also include one or more blades on the inlet face 242.

Rotation of the impeller 238 may draw hydrating fluid through the opening 232 and then expel the hydrating fluid axially downward and radially outward. Consequently, a region of relatively high pressure may develop between the lower housing portion 224 and the impeller 238, which may act to drive the hydrating fluid around the mixing chamber 214 and toward the slinger 236.

The flush line 220 may include an opening 250 defined in the lower housing portion 224 proximal to this region of high pressure. For example, the opening 250 may be defined in the interior surface 230 at a position between the outer radial extent of the impeller 238 and the opening 232 of the inlet 206. The flush line 220 may be or comprise a conduit 252 fluidly connected with an inlet 254 of the additive-receiving structure 208, for example, such that hydrating fluid is transported from the opening 250 into the additive-receiving structure 208 via the conduit 252. The hydrating fluid may then travel along a generally helical path along the inner surface 209 of the additive-receiving structure 208, as a result of the rotation of the slinger 236 and/or the shaft 212, until it travels through the additive inlet 206 to the slinger 236. Thus, the hydrating fluid received through the inlet 254 may generally form a wall of fluid along the inner surface 209 of the additive-receiving structure 208.

During operation, a pressure gradient may develop between the impeller 238 and the lower housing portion 224, with the pressure in the fluid increasing radially outward from the opening 232. Another gradient related to the concentration of the hydratable material in the hydrating fluid may also develop in this region, with the concentration of hydratable material increasing radially outward. In some cases, a high pressure head and low concentration may be intended, so as to provide a flow of relatively clean fluid through the flush line 220, propelled by the impeller/slinger assembly 210. Accordingly, the opening 250 for the flush line 220 may be disposed at a point along this region that realizes an optimal tradeoff between pressure head of the hydrating fluid and concentration of the hydratable material in the hydrating fluid received into the flush line 220.

The stator 218 may form a shearing ring extending around the impeller/slinger assembly 210 within the mixing chamber 214. For example, the stator 218 may be held generally stationary with respect to the rotatable impeller/slinger assembly 210, such as via fastening with the upper housing portion 222. However, the stator 218 may instead be supported by the impeller/slinger assembly 210 and may rotate therewith. In either example, the stator 218 may ride on the inlet face 240 of the slinger 236, or may be separated therefrom.

The stator 218 may include first and second annular portions 256, 258, which may be formed integrally or as discrete components connected together. The first annular portion 256 may minimize flow obstruction and may include a shroud 260 and posts 262 defining relatively wide slots 264, such as to permit relatively free flow of fluid there-through. In contrast, the second annular portion 258 may maximize flow shear, such as to promote turbulent mixing. For example, the second annular portion 258 may comprise a series of stator vanes 266 that are positioned closely together, in contrast to the wide spacing of the posts 262 of the first annular portion 256. Thus, narrow flowpaths 268 may be defined between the stator vanes 266, in contrast to the wide slots 264 of the first annular portion 256.

The sum of areas of the flowpaths 268 may be less than the sum of the areas of the stator vanes 266. The ratio of the collective flow-obstructing area of the stator vanes 266 to the collective flow-permitting area of the flowpaths 268 may

be about 1.5:1, for example. However, the ratio may range between about 1:2 and about 4:1, among other examples within the scope of the present disclosure. The flow-obstructing area of each stator vane **266** may be greater than the flow-permitting area of each flowpath **268**.

The stator vanes **266** may be disposed at various pitch angles with respect to the circumference of the stator **218**. For example, the axially extending surfaces of the stator vanes **266** may be substantially straight (e.g., substantially parallel to the diameter of the stator **218**) or slanted (e.g., to increase shear), whether in or opposite the direction of rotation of the impeller/slinger assembly **210**.

During mixing operations, the mixer **105** may reject air trapped in the hydratable material introduced into the mixing chamber **214**, thereby forming and discharging the concentrated fluid mixture that is substantially air free or having substantially less air than the amount of air introduced into the mixing chamber **214**.

Returning to FIG. 2, the mixer **105** may discharge the fluid mixture, hereinafter referred to as a concentrated fluid mixture, under pressure into the first container **125**. The first container **125** may be or comprise a continuous flow channel or pathway for communicating or conveying the concentrated fluid mixture over a period of time sufficient to permit adequate hydration to occur, such that the concentrated fluid mixture may reach a predetermined level of hydration and/or viscosity. The first container **125** may have a first-in-first-out mode of operation, and may comprise a vessel-type outer housing enclosing a receptacle having an elongated flow pathway or space operable to store and communicate the concentrated fluid mixture therethrough. The first container **125** may be an enclosed container, tank, or vessel, such as may permit the concentrated fluid mixture to be pressurized at an inlet of the first container and forced through the first container **125** until the concentrated fluid mixture is discharged at an outlet of the first container **125**.

The first container **125** may utilize the discharge pressure generated by the mixer as a motive force, such as may at least partially move or aid in the movement of the concentrated fluid mixture through the first container. In other words, the discharge pressure from the mixer **105** may push a viscous concentrated fluid mixture through one or more first containers **125**. In an example implementation, the mixer **105** may cause a concentrated fluid mixture having about 160 pounds or more of hydratable material per 1000 gallons of hydrating fluid to move through the first container **125**. The ability to hydrate the hydratable material within the hydrating fluid at higher concentrations may accelerate hydration rate of the hydratable material. For example, the hydration rate may increase by about 10% or more due to handling of a higher concentration gel in the first container **125**. For example, the rate of hydration may increase when handling gel that has about 80 pounds or more of hydratable material per 1000 gallons of hydrating fluid.

FIG. 4 is an expanded view of an example implementation of a portion of the first container **125** according to one or more aspects of the present disclosure. The first container **125** may comprise a plurality of enclosures **310**, **320**, **330**, **340**, which include a first enclosure **310**, a second enclosure **320**, and one or more intermediate enclosures **330**, **340**. The first container **125** may further comprise a first port **312** disposed on an outer wall **314** of the first enclosure **310** and operable to receive the concentrated fluid mixture, and a second port **322** disposed on an outer wall **324** of the second enclosure **320** and operable to discharge the concentrated fluid mixture. The ports **312**, **322** may be flush with or extend outward from the outer walls **314**, **324**, including

implementations in which the ports **312**, **322** extend outward in a tangential direction relative to the outer walls **314**, **324**.

The enclosures **310**, **320**, **330**, **340** may comprise separate chambers through which the concentrated fluid mixture may travel a distance over a time period sufficient for adequate hydration to occur. The enclosures **310**, **320**, **330**, **340** may collectively be in fluid communication, such as may permit the concentrated fluid mixture to be introduced into the first container **125** via the first port **312**, then through the first enclosure **310**, through the intermediate enclosures **330**, **340**, through the second enclosure **320**, and then discharged through the second port **322**.

The first container **125** may further comprise a first plate **350** connected to the first enclosure **310**, such as to confine the concentrated fluid mixture within the first enclosure **310** while passing through the first enclosure **310**. The first plate **350** may be connected to the first enclosure **310** by various means, including removable fasteners attaching with a flange **318** of the first enclosure **310**, welding, and/or other means, or may be formed as an integrated portion of the first enclosure **310**. The enclosures **310**, **320**, **330**, **340** may be connected with one another by same or similar means. For example, each of the enclosures **310**, **320**, **330**, **340** may comprise a flange **316**, **318**, **326**, **328**, **336**, **338**, **346**, **348** extending along the top and bottom of the outer walls **314**, **324**, **334**, **344**, such as for receiving threaded fasteners and/or other means for securing the enclosures **310**, **320**, **330**, **340** with one another.

Each of the enclosures **310**, **320**, **330**, **340** may comprise an interior space **360**, **370**, **380**, **390**. Each interior space **360**, **370**, **380**, **390**, may be or define at least one continuous fluid flow channel or other passageway **362**, **372**, **382**, **392**, respectively, each having a length greater than the circumferential length of the corresponding outer wall **314**, **324**, **334**, **344**. For example, each passageway **362**, **372**, **382**, **392** may be defined within the corresponding interior space **360**, **370**, **380**, **390** by a spiral or otherwise shaped wall **364**. The passageways **362**, **372**, **382**, **392** may be orientated and connected such that the first and second ports **312**, **322** are in fluid communication.

For example, during hydration operations, the concentrated fluid mixture may be introduced into the first port **312**, travel through the passageway **362**, and exit or otherwise discharge from the first enclosure **310** at a substantially central port **366** (shown in phantom lines). The concentrated fluid mixture may then flow into the first intermediate enclosure **330** at a central end **384** of the passageway **382**, travel through the passageway **382**, and exit from the first intermediate enclosure **330** into the second intermediate enclosure **340** through a port **386** (shown in phantom lines) extending vertically through the first intermediate enclosure **330**. The concentrated fluid mixture may then travel through the passageway **392** and exit from the second intermediate enclosure **340** into the second enclosure **320** through a port **396** (shown in phantom lines) extending vertically through the second intermediate enclosure **340**. The concentrated fluid mixture may then flow through the passageway **372** and exit through the second port **322**.

Although FIG. 4 show four enclosures **310**, **320**, **330**, **340**, the first container **125** may comprise one, two, three, five, or more enclosures within the scope of the present disclosure. Although FIGS. 2 and 4 show a single first container **125**, additional first containers, such as between two and five containers, may be connected in parallel and/or series if, for example, additional flow rates and/or longer hydration times are intended.

Furthermore, when multiple first containers **125** are utilized, the pressure drop across each first container **125** may be detected and utilized to determine the concentration, viscosity, and/or hydration level of the concentrated fluid mixture. When multiple first containers **125** are utilized, one or more in-line shearing and/or other mixing devices may be fluidly connected between instances of the first containers **125**, such as to increase the rate of hydration within the first containers **125**. The concentration of the concentrated fluid mixture flowing through the multiple first containers **125** may also be staged between each first container **125**, such as may permit more efficient sweep and cleanup of the concentrated fluid mixture at the end of the hydration operations.

During operation of the hydration system **100**, concentration slugs may be intentionally formed within the concentrated fluid mixture such that the slugs may produce pulsing of concentration in the concentrated fluid mixture as the concentrated fluid mixture travels through the first container **125**. Heat rejected from one or more components of the hydration system **100**, such as engines or motors, may also be transferred to the first container **125**, such as to heat the concentrated fluid mixture within the first container **125** to expedite hydration. The first container **125** may also be implemented with a gel-phobic coating or layer, such as may facilitate improved flow and decrease buildup on internal surfaces of the first container **125**. The passageways **362**, **372**, **382**, **392** and/or other portions of the first container **125** and other fluid conduits may also be purged by circulating a clean fluid (e.g., water, hydrating fluid) at velocities sufficient to create turbulence. The mixer **105**, a pump **140**, a first flow control device **145** (when implemented as a metering pump), an external pump, and/or other means may be utilized to circulate the clean fluid for such purging.

As depicted in FIG. 2, after the concentrated fluid mixture is discharged from the first container **125**, the concentrated fluid mixture may comprise a predetermined level of hydration and/or viscosity and may be transferred or communicated through a diluter **130**. FIG. 5 is a schematic view of an example implementation of the diluter **130** according to one or more aspects of the present disclosure.

The diluter **130** may be operable to mix or otherwise combine the concentrated fluid mixture with additional hydrating fluid or other aqueous fluid to dilute the concentrated fluid mixture or otherwise reduce the concentration of the hydratable material in the concentrated fluid mixture to a predetermined concentration level. The diluter **130** may be or comprise a fluid junction, a tee connection, a wye connection, an eductor, a mixing valve, an inline mixer, and/or another device operable to combine and/or mix two or more fluids. The diluter **130** may comprise a first passage **131** operable to receive a substantially continuous supply of concentrated fluid mixture, as indicated by arrow **101**, a second passage **132** operable to receive a substantially continuous supply of hydrating fluid, as indicated by arrow **102**, and a third passage **133** operable to discharge a substantially continuously supply of the diluted fluid mixture, as indicated by arrow **103**. The first passage **131** may be fluidly connected with the outlet port **322** of the first container **125**, such as may permit the concentrated fluid mixture to be transferred into the diluter **130**. The second passage **132** may be fluidly connected with the hydrating fluid source **120**, such as may permit the hydrating fluid to be transferred into the diluter **130**.

The hydrating fluid may be communicated to the diluter **130** by the pump **140**, which may be operable to pressurize and/or move the hydrating fluid from the hydrating fluid

source **120** to the diluter **130**. The pump **140** may be or comprise a centrifugal pump or another pump operable to transfer or otherwise substantially continuously move the hydratable material from the source **120** into the diluter **130**. For example, the pump **140** may move the hydrating fluid from the source **120** at a flow rate ranging between about zero barrels per minute (BPM) and about 150 BPM. However, the hydration system **100** is scalable, and the pump **140** may be operable at other flow rates.

The ratio of the concentrated fluid mixture and the hydrating fluid fed to the diluter **130**, which determines the concentration of the resulting diluted fluid mixture, may be controlled by adjusting a first flow control device **145**, operable to control the flow of the concentrated fluid mixture into the diluter **130**, and/or a second flow control device **150**, operable to control the flow of the hydrating fluid into the diluter **130**. For example, if the concentration of the diluted fluid mixture is selected to be decreased for use downstream, the concentration of the diluted fluid mixture may be decreased by decreasing the flow rate of the concentrated fluid mixture into the diluter **130**, via operation of the first flow control device **145**, and/or by increasing the flow rate of the hydrating fluid into the diluter **130**, via operation of the second flow control device **150**. The flow rate of the concentrated fluid mixture into the diluter **130** may be decreased by closing or otherwise reducing the flow area of the first flow control device **145**, and the flow rate of the hydrating fluid into the diluter **130** may be increased by opening or otherwise increasing the flow area of the second flow control device **150**. Similarly, if the concentration of the diluted fluid mixture is selected to be increased for use downstream, the concentration of the diluted fluid mixture may be increased by increasing the flow rate of the concentrated fluid mixture into the diluter **130** and/or by decreasing the flow rate of the hydrating fluid into the diluter **130**. The flow rate of the concentrated fluid mixture into the diluter **130** may be increased by opening or otherwise increasing the flow area of the first flow control device **145**, and the flow rate of the hydrating fluid into the diluter **130** may be decreased by closing or otherwise decreasing the flow area of the second flow control device **150**. The first and second flow control devices **145**, **150** may comprise various types of flow control valves, including needle valves, metering valves, butterfly valves, globe valves, or other valves operable to control the rate of fluid flow therethrough.

Each of the flow control devices **145**, **150** may comprise a flow-disrupting member **146**, **151**, such as may be a plate having a substantially circular configuration, and perhaps having a central opening or passageway **147**, **152** extending therethrough. The flow-disrupting members **146**, **151** may be selectively rotatable relative to the passages **131**, **132** to selectively open and close the passages **131**, **132**. Such rotation may be via operation of corresponding solenoids, motors, and/or other actuators (not shown).

FIG. 5 depicts the concentrated fluid mixture being introduced into the diluter **130** via the first passage **131** of the diluter **130**, and the hydrating fluid being introduced into the diluter **130** via the second passage **132**. However, the concentrated fluid mixture may be introduced via the second passage **132**, and the hydrating fluid may be introduced via the first fluid passage **131**.

In addition to or instead of the depicted flow control valve, the first flow control device **145** may comprise a metering pump operable to transfer the concentrated fluid mixture from the first container **125** to the diluter **130** at a predetermined flow rate. The metering pump may be a lobe

pump, a gear pump, a piston pump, or another positive displacement pump operable to move liquids at a selected flow rate.

A third flow control device **155** may also be disposed at the discharge or downstream of the diluter **130**. The third flow control device **155** may be operable to increase or decrease the output rate of the diluted fluid mixture discharged from the diluter **130** and introduced into a second container **135** of the hydration system **100**. It is noted that the combination of the flow control devices **145**, **150**, **155** may be further operable to increase and decrease the residence time of the concentrated fluid mixture in the first container **125** and, thus, increase the level of hydration and viscosity of the concentrated fluid mixture discharged by the first container **125**. For example, slower flow rates permit the concentrated fluid mixture to remain in the first container **125** for a longer period of time prior to introduction into the diluter **130** and/or the second container **135**.

Similarly to the first and second flow control devices **145**, **150**, the third flow control device **155** may comprise a flow-disrupting member **156**, such as may comprise a plate having a substantially circular configuration perhaps having a central opening or passageway **157** extending there-through. The third flow-disrupting member **156** may be selectively rotatable relative to the third passage **133** to selectively open and close the third passage **133**, perhaps in a manner similar to the selective rotation of the first and second flow-disrupting members **146**, **151**.

The first, second, and/or third flow-disrupting members **146**, **151**, **156** and/or other features of the first, second, and/or third flow control devices **145**, **150**, **155** may be further operable to disrupt flow or otherwise generate turbulence **134** in the flows of the concentrated fluid mixture, the hydrating fluid, and/or the diluted fluid mixture. Such turbulence **134** may provide mixing energy that may aid in dilution of the concentrated fluid mixture with the hydrating fluid to the predetermined concentration of hydratable material.

Returning to FIG. 2, the diluted fluid mixture discharged by the diluter **130** may be communicated to the second container **135**, where a supply of the diluted fluid mixture is stored prior to being utilized in downhole operations or as an ingredient or portion of another fluid mixture utilized in downhole operations. The second container **135** may also permit the diluted fluid mixture to further hydrate prior to being discharged. The second container **135** may be an open or enclosed vessel or a tank comprising one or more open spaces operable to receive and contain the diluted fluid mixture. However, the second container **135** may be omitted if sufficient hydration and/or viscosity level is achieved via one or more instances of the first container **125** and/or the diluter **130**. In such implementation, the diluted fluid mixture may be communicated directly downhole or utilized in another process before being injected downhole. For example, the diluted fluid mixture may be communicated to another mixer operable to mix proppants and/or other solid particulate material with the diluted fluid mixture to form a fracturing fluid or another fluid utilized in fracturing operations.

The second container **135** may comprise the same or similar structure and/or function as the first container **125**, or the second container **135** may be implemented as another type of first-in-first-out vessel or tank, such as may provide additional hydration time for the diluted fluid mixture. The second container **135** may also comprise one or more level sensors **137**, such as may be operable to generate signals or

information related to the amount of diluted fluid mixture contained within the second container **135**.

The hydration system **100** may also comprise a plurality of valves **181-186** operable to control flow of the hydrating fluid, the concentrated fluid mixture, or the diluted fluid mixture, depending on their location. The valves **181-186** may comprise ball valves, globe valves, butterfly valves, or other types of valves operable to control fluid flow there-through. For example, a first valve **181** may be operable to control flow of the hydrating fluid to the mixer **105**, a second valve **182** may be operable to control flow of the concentrated fluid mixture into the first container **125**, and a third valve **183** may be operable to control flow of the concentrated fluid mixture into the diluter **130**. A fourth valve **184** may be operable to control the supply of the hydrating fluid to the diluter **130**, a fifth valve **185** may be operable to control the supply of the concentrated fluid mixture discharged from the flow control device **145** back to the first container **125**, and a sixth valve **186** may be operable to control the supply of the concentrated fluid mixture discharged from the flow control device **145** to the pump **140**.

That is, the concentrated fluid mixture may be recirculated through the first container **125** via a recirculation flow path **126** comprising one or more pipes, hoses, and/or other fluid flow conduits, such as when an excess supply of the diluted fluid mixture exists in the second container **135**, or to provide additional hydration time for the concentrated fluid mixture. Accordingly, the third valve **183** may be closed and the fifth valve **185** may be opened to permit the concentrated fluid mixture to recirculate through the flow path **126** and then the first container **125**. During such recirculation operations, the first flow control device **145** (when implemented as a metering pump described above), may be operable to recirculate or otherwise move the concentrated fluid mixture through the recirculation flow path **126** and the first container **125**.

The concentrated fluid mixture may also be redirected through a redirected flow path **127** comprising one or more pipes, hoses, and/or other fluid flow conduits, such as for introduction to the hydrating fluid flowing between the hydrating fluid source **120** and the pump **140**. The combined hydrating fluid and concentrated fluid mixture may be simultaneously transferred and mixed by the pump **140** to dilute the concentrated fluid mixture and, thus, form the diluted fluid mixture. Accordingly, the third valve **183** may be closed to prevent the concentrated fluid mixture from entering the diluter **130**, and the sixth valve **186** may be opened to permit the concentrated fluid mixture to enter the fluid conduit(s) connecting the hydrating fluid source **120** and the pump **140**. Thereafter, the pump **140** may transfer the diluted fluid mixture into the second container **135** as described above or via another flow path **128** comprising one or more pipes, hoses, and/or other fluid flow conduits.

The hydration system **100** may also comprise a plurality of flow meters **160**, **165**, **170**, **175** operable to measure flow rates of selected fluids. The flow meter **160** may be disposed between the hydrating fluid source **120** and the mixer **105**, such as may facilitate monitoring the flow rate of the hydrating fluid being introduced into the mixer **105**. The flow meter **165** may be disposed between the hydrating fluid source **120** and the pump **140**, and the flow meter **175** may be fluidly connected between the pump **140** and the diluter **130**, such that one or both of the flow meters **165**, **175** may facilitate monitoring the flow rate of the hydrating fluid being introduced by the pump **140** into the diluter **130**. The flow meter **170** may be disposed between the diluter **130** and

the second container **135**, such as may facilitate monitoring the flow rate of the diluted fluid mixture being discharged from the diluter **130**.

The flow meters **160**, **165**, **170**, **175** may generate signals or information related to the corresponding fluid flow rates and communicate the signals to a controller **410**. The information generated by the flow meters **160**, **165**, **170**, **175** may be utilized by the controller **410** as a feedback signal, such as may facilitate a closed-loop control of the hydration system **100**. For example, the information may be utilized to check the accuracy of the flow control devices **145**, **150**, **155** and/or to adjust the flow rates of the corresponding fluids, such that the concentrations and flow rates of the concentrated and diluted fluid mixtures match setpoint values, which may be predetermined, selected by a human operator, and/or determined by the controller **410** during hydration operations.

FIG. **6** is a schematic view of at least a portion of an example implementation of the controller **410** in communication with the transfer device **115**, the mixer **105**, the pump **140**, the flow control devices **145**, **150**, **155**, the flow meters **160**, **165**, **170**, **175**, the valves **181-186**, the force sensors **112**, and the level sensors **137** (hereinafter referred to collectively as “hydration system components”) according to one or more aspects of the present disclosure. Such communication may be via wired and/or wireless communication means. However, for clarity and ease of understanding, such communication means are not depicted in FIG. **2**, and a person having ordinary skill in the art will appreciate that myriad means for such communication means are within the scope of the present disclosure.

The controller **410** may be operable to execute example machine-readable instructions to implement at least a portion of one or more of the methods and/or processes described herein, and/or to implement a portion of one or more of the example oilfield devices described herein. The controller **410** may be or comprise, for example, one or more processors, special-purpose computing devices, servers, personal computers, personal digital assistant (“PDA”) devices, smartphones, internet appliances, and/or other types of computing devices.

The controller **410** may comprise a processor **412**, such as a general-purpose programmable processor. The processor **412** may comprise a local memory **414**, and may execute coded instructions **432** present in the local memory **414** and/or another memory device. The processor **412** may execute coded instructions **432** that, among other examples, may include machine-readable instructions or programs to implement the methods and/or processes described herein. The processor **412** may be, comprise, or be implemented by one or a plurality of processors of various types suitable to the local application environment, and may include one or more of general-purpose computers, special-purpose computers, microprocessors, digital signal processors (“DSPs”), field-programmable gate arrays (“FPGAs”), application-specific integrated circuits (“ASICs”), and processors based on a multi-core processor architecture, as non-limiting examples. Of course, other processors from other families are also appropriate.

The processor **412** may be in communication with a main memory, such as may include a volatile memory **418** and a non-volatile memory **420**, perhaps via a bus **422** and/or other communication means. The volatile memory **418** may be, comprise, or be implemented by random access memory (RAM), static random access memory (SRAM), synchronous dynamic random access memory (SDRAM), dynamic random access memory (DRAM), RAMBUS dynamic ran-

dom access memory (RDRAM), and/or other types of random access memory devices. The non-volatile memory **420** may be, comprise, or be implemented by read-only memory, flash memory, and/or other types of memory devices. One or more memory controllers (not shown) may control access to the volatile memory **418** and/or the non-volatile memory **420**. The processor **412** may be further operable to cause the controller **410** to receive, collect, and/or record the concentration and flow setpoints and/or other information generated by the hydration system components and/or other sensors onto the main memory.

The controller **410** may also comprise an interface circuit **424**. The interface circuit **424** may be, comprise, or be implemented by various types of standard interfaces, such as an Ethernet interface, a universal serial bus (USB), a third generation input/output (3GIO) interface, a wireless interface, and/or a cellular interface, among other examples. The interface circuit **424** may also comprise a graphics driver card. The interface circuit **424** may also comprise a communication device, such as a modem or network interface card, such as to facilitate exchange of data with external computing devices via a network (e.g., via Ethernet connection, digital subscriber line (“DSL”), a telephone line, a coaxial cable, a cellular telephone system, a satellite, etc.).

The hydration system components may be connected with the controller **410** via the interface circuit **424**, such as may facilitate communication therebetween. For example, each of the hydration system components may comprise a corresponding interface circuit (not shown), which may facilitate communication with the controller **410**. Each corresponding interface circuit may permit signals or information generated by the hydration system components to be sent to the controller **410** as feedback signals for monitoring one or more of the hydration system components, or perhaps the entirety of the hydration system **100**. Each corresponding interface circuit may permit control signals to be received from the controller **410** by the various motors, drives, and/or other actuators (not shown) associated with ones of the hydration system components to control operation of the corresponding hydration system components, such as to control operation of the entirety of the hydration system **100**.

One or more input devices **426** may also be connected to the interface circuit **424**. The input devices **426** may permit a human operator to enter data and commands into the processor **412**, such as may include a setpoint corresponding to a predetermined concentration of the hydratable material in the diluted fluid mixture (hereinafter referred to as the “concentration setpoint”) and a setpoint corresponding to a predetermined flow rate of the diluted fluid mixture discharged by the hydration system **100** (hereinafter referred to as the “flow setpoint”). The input devices **426** may be, comprise, or be implemented by a keyboard, a mouse, a touchscreen, a track-pad, a trackball, an isopoint, and/or a voice recognition system, among other examples. One or more output devices **428** may also be connected to the interface circuit **424**, such as to display the concentration and flow setpoints and information generated by one or more of the hydration system components. The output devices **428** may be, comprise, or be implemented by visual display devices (e.g., a liquid crystal display (LCD) or cathode ray tube display (CRT), among others), printers, and/or speakers, among other examples.

The controller **410** may also comprise one or more mass storage devices **430** and/or a removable storage medium **434**, such as may be or include floppy disk drives, hard drive disks, compact disk (CD) drives, digital versatile disk (DVD) drives, and/or USB and/or other flash drives, among

other examples. The information generated by the hydration system components and/or other sensors may be stored on the one or more mass storage devices **430** and/or the removable storage medium **434**.

The coded instructions **432** may be stored in the mass storage device **430**, the volatile memory **418**, the non-volatile memory **420**, the local memory **414**, and/or the removable storage medium **434**. Thus, components of the controller **410** may be implemented in accordance with hardware (perhaps embodied in one or more chips including an integrated circuit, such as an application specific integrated circuit), or may be implemented as software or firmware for execution by one or more processors. In the case of firmware or software, the implementation may be provided as a computer program product including a computer readable medium or storage structure embodying computer program code (i.e., software or firmware) thereon for execution by the processor **412**.

The coded instructions **432** may include program instructions or computer program code that, when executed by the processor **412**, cause the hydration system **100** (or at least components thereof) to perform tasks as described herein. For example, the coded instructions **432**, when executed, may cause the controller **410** to receive and process the concentration and flow setpoints and, based on the setpoints, cause the hydration system **100** to form the diluted fluid mixture at the predetermined flow and having the predetermined concentration. When executed, the coded instructions **432** may cause the controller **410** to receive the information generated by hydration system components and process the information as feedback signals, such as may facilitate a closed-loop control of the hydration system **100** and/or the hydration system components. For example, the information may be processed to check the accuracy of the transfer device **115** and flow control devices **145**, **150**, **155**, and/or to adjust the flow rates of the hydratable material and corresponding fluids, such that the flow rate of the diluted fluid mixture and the concentrations of the concentrated and diluted fluid mixtures match the flow and concentration setpoints. Although flow and concentration setpoints are discussed herein, it is to be understood that the controller **410** may receive and process other setpoints within the scope of the present disclosure. The controller **410** may also monitor and control other parameters and operations of the hydration system **100**, such as may be implemented to form the diluted fluid mixture.

FIG. 7 is flow-chart diagram of at least a portion of an example control process **500** stored as coded instructions **432** and executed by the controller **410** and/or one or more other controllers associated with the hydration system components according to one or more aspects of the present disclosure. The following description refers to FIGS. 2, 6, and 7, collectively.

The process **500** may be implemented by the hydration system **100** to form the diluted fluid mixture based on the predetermined concentration and flow setpoints entered into the controller **410** by a human operator. The process **500** may comprise a series of interrelated stages or sub-processes **510**, **520**, **530**, **540**, **550**, wherein each such sub-process may employ a separate control loop, such as a proportional-integral-derivative (PID) control loop. For example, one or more of the sub-processes **510**, **520**, **530**, **540**, **550** may utilize a control loop to achieve an intended output or result. The sub-processes **510**, **520**, **530**, **540**, **550** may be interrelated, as depicted by arrows **522**, **532**, **542**, **552**.

The sub-process **510** may comprise a determination of a concentrated fluid mixture (“CFM”) concentration setpoint

and a dilution ratio. Inputs to this sub-process may include a diluted fluid mixture (“DFM”) concentration setpoint **512** (hereinafter “first setpoint”) and a maximum diluted fluid mixture flow rate setpoint **514** (hereinafter “second setpoint”), which may be compared against the information generated by the flow meter **170**. The first and second setpoints **512**, **514** may be predetermined or selected parameters that are specific to a wellsite operation to be executed utilizing the hydration system **100**, such as a hydraulic fracturing operation. The first and second setpoints **512**, **514** may be entered into the controller **410** in a suitable manner, such as via the input devices **426**. The setpoints **512**, **514** may be determined based on other information that is relevant to the wellsite operation, such as characteristics of a subterranean formation (e.g., size, location, content, etc.) into which the diluted fluid mixture discharged by the hydration system **100** is to be injected. The controller **410** may determine and output other parameters utilized during hydration operations based on the entered first and second setpoints **512**, **514** and/or other inputs. The controller **410** may then communicate the other parameters to one or more equipment controllers (not shown) associated with the hydration system components, which in turn, may implement additional sub-processes.

The sub-process **520** may comprise the control of the transfer device **115** for transferring hydratable material to the mixer **105**. Inputs to the sub-process **520** may include one or more outputs (e.g., setpoints) generated by the sub-process **510**, along with an actual hydrating fluid flow rate **526** into the mixer **105**, as determined by the flow meter **160**. Signals generated by the one or more force sensors **112**, such as load cells that support the hydratable material source **512**, may be utilized in the sub-process **520** to ensure that an appropriate amount of hydratable material is being introduced into the mixer **105**, and/or to compare the expected amount of hydratable material with an actual amount of hydratable material introduced into the mixer **105**.

The sub-process **530** may comprise the determination of the diluted fluid mixture flow rate setpoint, which includes determination of the concentrated fluid mixture flow rate setpoint and the hydrating fluid flow rate setpoint (indicated in FIG. 7 as “Dilution Rate Setpoint”). The inputs to the sub-process **530** may include one or more of the outputs generated by the sub-process **510**, along with a total hydrating fluid flow rate **534** into the diluter **130**, as determined by one or more of the flow meters **160**, **165**, **175**, and a diluted fluid mixture level **536** in the second container **135**, as determined by the level sensor **137**.

The sub-process **540** may comprise control of the concentrated fluid mixture flow rate into the diluter **130**, which may be a function of the first flow control device **145**. The inputs to the sub-process **540** may include a concentrated fluid mixture flow rate setpoint **542** generated by the sub-process **530**, along with an actual concentrated fluid mixture flow rate **544**, as determined by the first flow control device **145** or a flow meter (not shown).

The sub-process **550** may comprise control of the hydrating fluid flow rate into the diluter **130**, such as to control dilution of the concentrated fluid mixture. Inputs to the sub-process **550** may include a dilution rate setpoint **552** generated by the sub-process **530**, along with a hydrating fluid flow rate **554** into the diluter **130**, as determined by one or more of the flow meters **165**, **175**.

FIG. 8 is a perspective view of an example implementation of the hydration system **100** shown in FIG. 2 according to one or more aspects of the present disclosure. The hydration system **100** is depicted in FIG. 8 as being imple-



mented as a mobile hydration system **600** detachably connected with a prime mover **602**. The mobile hydration system **600** comprises a mobile carrier **603** having a frame **604** and a plurality of wheels **606** rotatably connected to the frame **604** and supporting the frame **604** on the ground **610**. The mobile hydration system **600** may further comprise a control cabin **612**, which may be referred to in the art as an E-house, connected with the frame **604**. The control cabin **612** may comprise one or more controllers, such as the controller **410** shown in FIGS. **2** and **6**, and which may be operable to monitor and control the mobile hydration system **600** as described above with respect to the hydration system **100**.

The mobile hydration system **600** further comprises the hydratable material source **110**, implemented as a hopper or bin operable to receive hydratable material therein. The hydratable material source **110** is connected to the frame **604** by, for example, a plurality of support members **616**.

The mobile hydration system **600** further comprises the mixer **105** and the hydratable material transfer device **115**, such as a screw feeder and/or other device operable to meter the hydratable material into the mixer **105**. The mixer **105** is connected with the frame **604** and comprises a motor **621** operable to drive the mixer **105**. The mixer **105** may be or comprise the solid-fluid mixer **105** as depicted in FIG. **3** or another mixer operable to mix or blend hydrating fluid with hydratable material. The hydrating fluid may be supplied to the mixer **105** from a hydrating fluid source **120**, which is depicted in FIG. **8** as being implemented as a manifold operable to receive hydrating fluid via a plurality of ports **624**. Each of the ports **624** may comprise a valve **625**, such as may be operable to control the flow of hydrating fluid.

After the hydratable material and hydrating fluid are blended within the mixer **105** to form the concentrated fluid mixture, the concentrated fluid mixture may be communicated into and through one or more instances of the first container **125**. The first container **125** is depicted in FIG. **8** as being implemented as four enclosed hydrating containers (hereinafter "hydrators") each comprising a substantially continuous flow pathway extending therethrough, such as the example implementation depicted in FIG. **4**. Thus, each first container **125** may comprise first and second ports **312**, **322** operable to receive or discharge the concentrated fluid mixture into or from each first container **125**. Each first container **125** may be connected to the frame **604** by, for example, a plurality of support members **632**.

After the concentrated fluid mixture is passed through each first container **125**, the concentrated fluid mixture may be communicated into the second container **135**, which is depicted in FIG. **8** as being implemented as a header tank. Prior to being introduced into the second container **135**, additional hydrating fluid may be combined with or added to the concentrated fluid mixture via the diluter **130**, which is depicted in FIG. **8** as being implemented as a piping tee. The hydrating fluid may be transferred from the hydrating fluid source **120** to the diluter **130** by the pump **140**, such as a centrifugal pump driven by a motor **640**. The hydrating fluid and the concentrated fluid mixture may be combined within the diluter **130** to form the diluted fluid mixture, as described above, and communicated into the second container **135**. The diluted fluid mixture may be discharged from the second container **135** via an outlet port **642**, which may be opened and closed with a valve **644**. The second container **135** may be connected to the frame **604** by, for example, a plurality of support members **646**.

FIG. **9** is a schematic view of an example implementation of a portion of the mobile hydration apparatus **600** shown in

FIG. **8** according to one or more aspects of the present disclosure. FIG. **9** depicts the hydratable material source **110** as being implemented as comprising a substantially conical hopper section **615**, and further comprising or otherwise being utilized in conjunction with an activator system **650**. The activator system **650** comprises an internal baffle **652** rigidly attached to a hopper **617** and/or other component of the hydratable material source **110** by, for example, a plurality of structural members **654**. The baffle **652** may be substantially conical, convex, or otherwise shaped, and may be substantially solid or have a plurality of small holes forming a sieve. A compliant membrane (not shown) may extend between a cylindrical bin section **614** and/or other portion of the activator system **650** and the conical hopper section **615** of the hydratable material source **110**, such as to prevent hydratable material from passing upward around the outside of the conical hopper section **615** of the hydratable material source **110**, and/or to minimize dust generation. The bin section **614**, hopper **617**, and/or other components of the activator system **650** may move or vibrate horizontally in response to centrifugal forces generated by a vibrator **656**, such as may comprise unbalanced rotating weights therein. The vibrator **656** may be connected to the bin section **614** and/or other component of the activator system **650** by one or more clamps, threaded fasteners, and/or other means. During hydration operations, the activator system **650** may break apart clumps of hydratable material moving from the conical hopper section **615** to the hopper **617** past the baffle **652**, as indicated by arrows **660**. The vibration or motion generated by the activator system **650** may aid in mitigating rat-hole formation tendencies of the hydratable material being fed from the hydratable material source **110**.

Table 1 set forth below lists example specifications and/or operating parameters of the mobile hydration system **600**. However, Table 1 merely provides example values, and many other values are also within the scope of the present disclosure.

TABLE 1

HM source 110 capacity	4000 lb minimum
HM source 110 input means	2-inch port 111 for pneumatic transfer with dust collection
Maximum HM transfer rate	135 lb/min
HM transfer device 115	Volumetric screw feeder and loss in weight automated calibration
Maximum mixing rate of mixer 105 (at 70 degrees F.)	Up to 120 BPM and 120 lb/1000 gal
Hydration time at maximum rate through first containers 115	150 seconds
First container 115 pressure rating	80 pounds/in <sup>2</sup> (psi); ASME rated
Mixer 105 maximum operating point	27 BPM at 55 psi discharge

FIG. **10** is a flow-chart diagram of at least a portion of an example implementation of a method (**700**) according to one or more aspects of the present disclosure. The method (**700**) may be performed utilizing at least a portion of one or more implementations of the apparatus shown in one or more of FIGS. **2-9** and/or other apparatus within the scope of the present disclosure. For the sake of clarity and ease of understanding, however, the following description of the method (**700**) depicted in FIG. **10** also collectively refers to FIGS. **2** and **8** by way of example.

The method (**700**) comprises communicating (**705**) a substantially continuous stream of gel having a first concentration. As described above, the gel may be a mixture of hydratable material and hydrating fluid. Thus, for example, such communication (**705**) may be via a discharge means of

the mixer 105, such as the outlet 216 shown in FIG. 3, and/or one or more pipes, hoses, and/or other conduits (hereinafter collectively referred to as “conduits”) fluidly connecting the mixer 105 with one or more instances of the first container 125. Such communication (705) may also or instead be through one or more instances of the first container 125, such as to permit sufficient hydration of the substantially continuous stream of gel having the first concentration. Such communication (705) may also or instead be via a discharge means of the furthest downstream instance of the first container 125 (where multiple instances of the first container 125 are utilized), such as the port 322 shown in FIG. 4, and/or one or more conduits fluidly connecting the furthest downstream instance of the first container 125 with the diluter 130. Such communication (705) may also or instead be via one or more other components shown in one or both of FIGS. 2 and 8, such as the valve 182, the flow control device 145, the valve 183, the flow path 126, the valve 185, the flow path 127, the valve 186, the pump 140, the flow control device 150, and/or one or more conduits thereof and/or therebetween.

The method (700) also comprises communicating (710) a substantially continuous stream of aqueous fluid. Such communication (710) may be via one or more of the ports 624 and/or one or more conduits fluidly connecting one or more of the ports 624 with the diluter 130. Such communication (710) may also or instead be via one or more other components shown in one or both of FIGS. 2 and 8, such as one or both of the flow meters 165, 175, the valve 184, the pump 140, the flow control device 150, and/or one or more conduits thereof and/or therebetween.

The method (700) also comprises combining (715) the substantially continuous streams of gel having the first concentration and aqueous fluid to form a substantially continuous stream of gel having a second concentration, wherein the second concentration is substantially lower than the first concentration. Such combination (715) may be via the diluter 130 and/or one or more other components and/or conduits shown in one or both of FIGS. 2 and 8.

Combining (715) the substantially continuous streams of gel having the first concentration and aqueous fluid to form the substantially continuous stream of gel having the second concentration may comprise changing the second concentration by changing at least one of: a first flow rate of the substantially continuous stream of gel having the first concentration; and a second flow rate of the substantially continuous stream of aqueous fluid. Changing the first flow rate may comprise operating one or more flow control devices, such as may include one or more of the flow control device 145, the valve 183, the valve 185, and/or the valve 186. Changing the second flow rate may also comprise operating one or more flow control devices, such as may include one or more of the valve 184, the pump 140, and/or the flow control device 150. However, changing at least one of the first and second flow rates to decrease the concentration may also or instead comprise one or more other flow control devices. Changing at least one of the first and second flow rates to decrease the concentration may comprise decreasing the first flow rate, increasing the second flow rate, or both.

The method (700) may further comprise, before combining (715) the substantially continuous streams of gel having the first concentration and aqueous fluid to form the substantially continuous stream of gel having the second concentration, generating (720) turbulence in the substantially continuous stream of gel having the first concentration. For example, if the diluter 130 is implemented as depicted in

FIG. 5, and the substantially continuous stream of gel having the first concentration is introduced into the diluter 130 via the passage 131, such turbulence may be generated (720) via operation of the flow-disrupting member 146. However, implementations of the flow control device 145 other than as depicted in FIG. 5, and/or other means, may also or instead be utilized to generate (720) turbulence in the substantially continuous stream of gel having the first concentration. The generated (720) turbulence may aid in mixing, dilution, and/or hydration of the resulting mixture.

The method (700) may further comprise, before combining (715) the substantially continuous streams of gel having the first concentration and aqueous fluid to form the substantially continuous stream of gel having the second concentration, generating (725) turbulence in the substantially continuous stream of aqueous fluid. For example, if the diluter 130 is implemented as depicted in FIG. 5, and the substantially continuous stream of aqueous fluid is introduced into the diluter 130 via the passage 132, such turbulence may be generated (725) via operation of the flow-disrupting member 151. However, implementations of the flow control device 150 other than as depicted in FIG. 5, and/or other means, may also or instead be utilized to generate (725) turbulence in the substantially continuous stream of aqueous fluid. The generated (725) turbulence may aid in mixing, dilution, and/or hydration of the resulting mixture.

The method (700) may further comprise mixing (730) a substantially continuous stream of hydratable material with a substantially continuous stream of aqueous fluid to form the communicated (705) substantially continuous stream of gel having the first concentration. As described above, such mixing (730) may be performed by the mixer 105 upon receiving a substantially continuous supply of the hydratable material, such as from the hydratable material source 110 via the transfer device 115, and a substantially continuous supply of the aqueous fluid, such as from one or more of the ports 624 shown in FIG. 8 and/or the hydrating fluid source 120 shown in FIG. 2.

The method (700) may further comprise communicating (735) the substantially continuous stream of gel having the second concentration into a tank. For example, the tank may be one or more instances of the second container 135. Such communication (735) may be via a discharge means of the diluter 130 (such as the passage 133 shown in FIG. 5), the flow control device 155, and/or one or more other components or conduits fluidly connected between the diluter 130 and the second container 135.

The method (700) may further comprise utilizing (740) the gel having the second concentration in a well fracturing operation. For example, utilizing (740) the gel having the second concentration may comprise mixing the gel with proppant material, and perhaps other additives, to form a fracturing fluid, such as may be subsequently pressurized and injected downhole for fracturing a subterranean formation. Such mixing may utilize another instance of the mixer 105, and/or another type of mixer, operable to receive a substantially continuous supply of the proppant material and/or other additives and the gel having the second concentration, whether the gel is received from the diluter 130, the second container 135, and/or another component of the hydration system 100 shown in FIG. 2 and/or of the mobile hydration system 600 shown in FIG. 8.

The method (700) may further comprise, before utilizing (740) the gel having the second concentration in the well fracturing operation, generating (745) turbulence in the substantially continuous stream of gel having the second

concentration. For example, if the diluter **130** is implemented as depicted in FIG. **5**, and the substantially continuous stream of gel having the second concentration is discharged from the diluter **130** via the passage **133**, such turbulence may be generated (**745**) via operation of the flow-disrupting member **156**. However, implementations of the flow control device **155** other than as depicted in FIG. **5**, and/or other means, may also or instead be utilized to generate (**745**) turbulence in the substantially continuous stream of gel having the second concentration. The generated (**745**) turbulence may aid in mixing, dilution, and/or hydration of the resulting mixture.

The method (**700**) may further comprise transporting (**750**) a mobile carrier to a wellsite at which the well fracturing operation is to be performed. For example, the transported (**750**) mobile carrier may be the mobile hydration system **600** shown in FIG. **8**. Thus, the transported (**750**) mobile carrier may comprise the frame **604** and the plurality of wheels **606** rotatably coupled to the frame **604**, and may be detachably connectable to a prime mover **602**. As described above, the mixer **105**, one or more instances of the first container **125** collectively forming an enclosed hydrator, and the diluter **130** are each coupled to the frame **604**. In such implementations, the diluter **130** may also be referred to as a combiner operable for substantially continuously combining the substantially continuous streams of aqueous fluid and gel having the first (higher) concentration to form the substantially continuous stream of gel having the second (lower) concentration.

In view of the entirety of the present disclosure, including the claims and the figures, a person having ordinary skill in the art should readily recognize that the present disclosure introduces a method comprising: communicating a substantially continuous stream of gel having a first concentration; communicating a substantially continuous stream of aqueous fluid; combining the substantially continuous streams of gel having the first concentration and aqueous fluid to form a substantially continuous stream of gel having a second concentration, wherein the second concentration is substantially lower than the first concentration; and utilizing the gel having the second concentration in a well fracturing operation.

The method may further comprise: mixing a substantially continuous stream of hydratable material with a substantially continuous stream of aqueous fluid with a mixer to form the gel having the first concentration; and discharging the gel having the first concentration from the mixer as the substantially continuous streams of hydratable material and aqueous fluid are being mixed to form the substantially continuous stream of gel having the first concentration. The hydratable material may substantially comprise guar. The aqueous fluid may substantially comprise water.

The method may further comprise, before combining the substantially continuous streams of gel having the first concentration and aqueous fluid to form the substantially continuous stream of gel having the second concentration, communicating the substantially continuous stream of gel having the first concentration through a hydration tank to permit the substantially continuous stream of gel having the first concentration to reach a predetermined viscosity.

The method may further comprise, before utilizing the gel having the second concentration in the well fracturing operation, communicating the substantially continuous stream of gel having the second concentration into a tank.

The method may further comprise, before combining the substantially continuous streams of gel having the first concentration and aqueous fluid to form the substantially

continuous stream of gel having the second concentration, generating turbulence in the substantially continuous stream of gel having the first concentration.

The method may further comprise, before combining the substantially continuous streams of gel having the first concentration and aqueous fluid to form the substantially continuous stream of gel having the second concentration, generating turbulence in the substantially continuous stream of aqueous fluid.

The method may further comprise, before utilizing the gel having the second concentration in the well fracturing operation, generating turbulence in the substantially continuous stream of gel having the second concentration.

The method may further comprise changing the second concentration by changing at least one of: a first flow rate of the substantially continuous stream of gel having the first concentration; and a second flow rate of the substantially continuous stream of aqueous fluid. Changing at least one of the first and second flow rates may comprise operating a flow control device. The flow control device may comprise a valve and/or a pump. Changing at least one of the first and second flow rates may comprise at least one of: decreasing the first flow rate to decrease the second concentration; and increasing the second flow rate to decrease the second concentration.

The present disclosure also introduces a method comprising: substantially continuously feeding hydratable material and hydrating fluid into a mixer; substantially continuously operating the mixer to mix the hydratable material and the hydrating fluid to form a first substantially continuous stream, wherein the first substantially continuous stream comprises gel having: a first concentration of hydratable material; and a first viscosity; substantially continuously communicating the first substantially continuous stream through an enclosed hydrator to form a second substantially continuous stream, wherein the second substantially continuous stream comprises gel having: the first concentration of hydratable material; and a second viscosity that is substantially greater than the first viscosity; substantially continuously combining the second substantially continuous stream and a third substantially continuous stream to form a fourth substantially continuous stream, wherein the third substantially continuous stream substantially comprises aqueous fluid, and wherein the fourth substantially continuous stream comprises gel having a second concentration of hydratable material that is substantially less than the first concentration; and utilizing gel from the fourth substantially continuous stream in a well fracturing operation.

The hydratable material may substantially comprise guar. The hydrating fluid and the aqueous fluid may each substantially comprise water.

Substantially continuously combining the second and third substantially continuous streams to form the fourth substantially continuous stream may comprise adjusting a flow rate of at least one of the second and third substantially continuous streams to change the second concentration. Adjusting the flow rate of at least one of the second and third substantially continuous streams may comprise operating a flow control valve. Adjusting the flow rate of at least one of the second and third substantially continuous streams may comprise adjusting operation of an associated pump.

The method may further comprise communicating the fourth substantially continuous stream into a tank before utilizing gel from the fourth substantially continuous stream in the well fracturing operation. In such implementations,

the gel from the fourth substantially continuous stream utilized in the well fracturing operation may be obtained from the tank.

The method may further comprise generating turbulence in the second substantially continuous stream before combining the second and third substantially continuous streams.

The method may further comprise generating turbulence in the third substantially continuous stream before combining the second and third substantially continuous streams.

The method may further comprise generating turbulence in the fourth substantially continuous stream.

The method may further comprise transporting a mobile carrier to a wellsite at which the well fracturing operation is performed. The mobile carrier may comprise a frame and a plurality of wheels rotatably coupled to the frame. The mobile carrier may be detachably connectable to a prime mover. The mixer, the enclosed hydrator, and a combiner may be coupled to the frame. The combiner may be operable for substantially continuously combining the second and third substantially continuous streams to form the fourth substantially continuous stream.

The present disclosure also introduces an apparatus comprising: a system operable to form a substantially continuous supply of gel having a first hydratable material concentration for use in a well fracturing operation, wherein the system comprises: a mixer operable to receive and mix hydratable material and aqueous fluid to form a substantially continuous supply of gel having a second hydratable material concentration, wherein the second hydratable material concentration is substantially higher than the first hydratable material concentration; an enclosed tank having an internal flow path traversed by the substantially continuous supply of gel having the second hydratable material concentration during a period of time sufficient to permit a viscosity of the substantially continuous supply of gel having the second hydratable material concentration to increase to a predetermined level; and a diluter operable to dilute the substantially continuous supply of increased viscosity gel having the second hydratable material concentration to substantially continuously supply gel having the first hydratable material concentration.

The system may further comprise a tank operable to receive the substantially continuous supply of gel having the first hydratable material concentration.

The system may further comprise at least one of: a first flow control device operable to control a first flow rate of the substantially continuous supply of increased viscosity gel having the second hydratable material concentration to the diluter; and a second flow control device operable to control a second flow rate of aqueous fluid to the diluter. At least one of the first and second flow control devices may comprise a flow control valve. At least one of the first and second flow control devices may be disposed adjacent the diluter and may comprise a flow-disrupting member operable to generate turbulence of passing fluid flow. The flow-disrupting member may be a substantially circular plate having a central passage. The flow-disrupting member may be selectively rotatable relative to a conduit containing the passing fluid flow. At least one of the first and second flow control devices may comprise a pump operable to meter flow to the diluter.

The system may further comprise: a first pump operable to transfer aqueous fluid from a source of aqueous fluid to the mixer; and a second pump operable to transfer aqueous fluid from the source of aqueous fluid to the diluter for use

in diluting the substantially continuous supply of increased viscosity gel having the second hydratable material concentration.

The hydratable material may substantially comprise guar. The hydratable material may comprise a polymer, a synthetic polymer, a galactomannan, a polysaccharide, a cellulose, a clay, or a combination thereof. The aqueous fluid may substantially comprise water.

The enclosed tank may be a first-in-first-out tank having a channelized flow path. The mixer may be further operable to substantially continuously pressurize the substantially continuous supply of gel having the second hydratable material concentration to cause the substantially continuous supply of gel having the second hydratable material concentration to substantially continuously traverse the channelized flow path.

The diluter may comprise having a first passage receiving the substantially continuous supply of increased viscosity gel having the second hydratable material concentration, a second passage receiving a substantially continuous supply of aqueous fluid, and a third passage conducting the substantially continuously supply of gel having the first hydratable material concentration. The diluter may be a piping tee.

The system may further comprise a frame operatively coupled with a plurality of wheels supporting the frame on the ground. In such implementations, the mixer, the enclosed tank, and the diluter may be connected with the frame. The frame may be detachably connected with a prime mover.

The foregoing outlines features of several implementations so that a person having ordinary skill in the art may better understand the aspects of the present disclosure. A person having ordinary skill in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same functions and/or achieving the same benefits of the implementations introduced herein. A person having ordinary skill in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

The Abstract at the end of this disclosure is provided to comply with 37 C.F.R. § 1.72(b) to permit the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

What is claimed is:

1. A method, comprising:

using a hydratable material transfer device to meter a hydratable material from a hydratable material source to provide a continuous stream of the hydratable material;

mixing the continuous stream of the hydratable material with a first continuous stream of aqueous fluid in a mixer to form a hydrated gel;

using a discharge pressure of the mixer to force a continuous stream of the hydrated gel through at least one hydration tank to achieve a first concentration and a viscosity of the hydrated gel at an outlet of the at least one hydration tank;

combining, at a diluter, the continuous stream of the hydrated gel having the first concentration and a second continuous stream of aqueous fluid to form a continuous stream of hydrated gel having a second selected concentration, wherein the second selected concentration is lower than the first concentration, wherein the diluter is operable to change the second selected con-

centration by changing a flow rate of at least one of the continuous stream of hydrated gel having the first concentration and the second continuous stream of aqueous fluid; and  
 utilizing the hydrated gel having the second selected concentration in a well fracturing operation. 5  
 2. The method of claim 1 wherein:  
 the hydratable material comprises guar; and  
 the aqueous fluid comprises water.  
 3. The method of claim 1 further comprising, before 10  
 utilizing the hydrated gel having the second selected concentration in the well fracturing operation, communicating the continuous stream of hydrated gel having the second selected concentration into a tank.  
 4. The method of claim 1 further comprising, before 15  
 combining the continuous streams of hydrated gel having the first concentration and aqueous fluid to form the continuous stream of hydrated gel having the second selected concentration, generating turbulence in the continuous stream of hydrated gel having the first concentration via one or more flow disrupting members. 20  
 5. The method of claim 1 further comprising, before  
 combining the continuous stream of hydrated gel having the first concentration and the second continuous stream of aqueous fluid to form the continuous stream of hydrated gel 25  
 having the second selected concentration, generating turbulence in the continuous stream of aqueous fluid via one or more flow disrupting members.  
 6. The method of claim 1 further comprising, before 30  
 utilizing the hydrated gel having the second selected concentration in the well fracturing operation, generating turbulence in the continuous stream of hydrated gel having the second selected concentration via one or more flow disrupting members.  
 7. The method of claim 1 further comprising changing the 35  
 second selected concentration by changing at least one of:  
 a first flow rate of the continuous stream of hydrated gel having the first concentration; and  
 a second flow rate of the second continuous stream of aqueous fluid. 40  
 8. The method of claim 7 wherein changing at least one of the first and second flow rates comprises at least one of:  
 decreasing the first flow rate to decrease the second selected concentration; and  
 increasing the second flow rate to decrease the second 45  
 selected concentration.  
 9. The method of claim 1 wherein utilizing the hydrated gel having the second selected concentration in a well fracturing operation comprises communicating the hydrated gel with the second selected concentration directly down-hole from the diluter to the well.  
 10. The method of claim 1 wherein the at least one hydration tank comprises a volume that provides a residence

time to permit the continuous stream of hydrated gel having the first concentration to reach the viscosity.  
 11. The method of claim 1 comprising forcing the continuous stream of hydrated gel having the first concentration through an internal flow path of the at least one hydration tank defined by a plurality of enclosed hydrating containers of the at least one hydration tank.  
 12. The method of claim 1 comprising forcing the continuous stream of hydrated gel having the first concentration in a first-in, first-out manner through a channelized flow path of the at least one hydration tank.  
 13. The method of claim 12 comprising continuously pressurizing the continuous stream of hydrated gel having the first concentration to cause the continuous stream of hydrated gel having the first concentration to be forced through the channelized flow path of the at least one hydration tank.  
 14. The method of claim 1 comprising communicating the continuous stream of hydrated gel having the first concentration through a plurality of hydration tanks.  
 15. The method of claim 1 comprising utilizing a controller to:  
 receive, via a plurality of sensors, concentration data relating to the continuous stream of the hydrated gel having the first concentration; and  
 determine that the continuous stream of hydrated gel having the first concentration has the first concentration and the viscosity.  
 16. The method of claim 15, wherein the controller is configured to determine that the continuous stream of the hydrated gel having the first concentration has the viscosity based at least in part on a pressure drop across the at least one hydration tank.  
 17. The method of claim 15, wherein the controller is configured to:  
 receive, via a plurality of flow meters, flow rate data relating to the continuous stream of the hydrated gel having the first concentration, the second continuous stream of aqueous fluid, and the continuous stream of hydrated gel having the second selected concentration; and  
 determine that flow rates of the continuous stream of the hydrated gel having the first concentration, the second continuous stream of aqueous fluid, and the continuous stream of hydrated gel having the second selected concentration each match flow rate setpoints.  
 18. The method of claim 1 wherein the hydratable material transfer device controls the volumetric or mass flow rate of the hydratable material from the hydratable material source to the mixer.

\* \* \* \* \*